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FOREST RESOURCE DEVELOPMENT AGREEMENT
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES

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The Canada-Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by the Canadian Forestry Service and the Alberta Forest Service.

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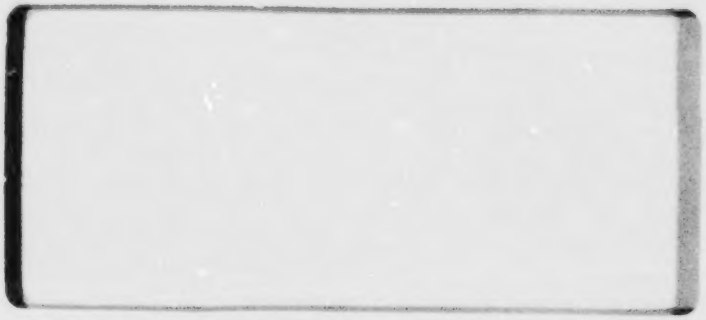

For more information, please call or write:

Pour de plus amples informations, veuillez vous adresser à:

Canadian Forestry Service
Northern Forestry Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5
Telephone: (403) 435-7210
Attention: S. Price

OR/OU Alberta Department of
Forestry, Lands & Wildlife
9915 - 108 Street
Edmonton, Alberta
T5K 2C9
Telephone: (403) 427-3583
Attention: D. Fregren

REVIEW OF PULPING AND PAPERMAKING PROPERTIES OF ASPEN

Arbokem Inc.*
Al Wong, P. Eng.

April 1987

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*C.P. 187, Beaconsfield, Quebec H9W 5T7, CANADA

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REVIEW OF PULPING AND PAPERMAKING PROPERTIES OF ASPEN

Abstract

A review of available information on the pulping and papermaking properties of aspen has been completed. This study has confirmed that there is already considerable technical literature in existence. The main topics reviewed were:

* Mechanical Pulping
* Chemimechanical Pulping
* Chemical Pulping

The papermaking aspects of aspen pulp were reviewed in the context of the specific pulping process. Technical information pertaining to special problems of aspen usage within pulp and paper mills has also been examined. These topics include 1) stained and decayed wood,2) bark content and debarking,and 3) pitch deposition and de-resination.

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REVIEW OF PULPING AND PAPERMAKING PROPERTIES OF ASPEN

Summary

BACKGROUND

Poplar is the common name applied to trees of the genus POPULUS which includes aspens, black or balsam poplars and cottonwoods. Its domain ranges from Newfoundland to British Columbia. The commercial growing stock of poplars is estimated to be about 2.25 billion m^3. Alberta accounts for about 27% of the total, equivalent to about 600 million m^3. Aspen (Populus tremuloides Michx.) accounts for about 80% of the commercial poplars in Alberta.

The technical and economical benefits of using aspen/poplar has been promoted many times in Canada since the late 1910's. But the time was not right for over 70 years. Because of the abundant availability of softwoods in Canada, the usage of aspen for pulp manufacture has been largely ignored until very recently.

With growing relative abundance of the aspen resource, there is a timely need to assess available technical information on the usage of aspen for pulping and papermaking.

OBJECTIVES

The objectives of the present study were as follows:

a) To review critically the available technical literature pertaining to the pulping and papermaking properties of aspen (Populus tremuloides Michx.),

b) To identify any deficiencies in the above technical data base, and

c) To recommend future course of action pertaining to the development of relevant data base for the exploitation of aspen as a raw material for the pulp and paper industry

RESULTS

A detailed review of available technical information on aspen pulping and pulp properties has been completed. The papermaking aspects of aspen pulp were reviewed in the context of the specific pulping process. The major findings are as follows:

1. Aspen can be and has been used for the production of good quality mechanical,chemimechanical and chemical pulps.

   The use of market aspen pulp,chemimechanical (e.g.,CMP and CTMP) and chemical (e.g.,kraft),is still relatively new in the manufacture of paper and paperboard.

2. Aspen mechanical pulp has been used as a major furnish (up to 30%) component for the manufacture of coated and uncoated groundwood publication papers.

   It may be produced by the classical stone groundwood, pressurized groundwood,refiner and thermomechanical pulping methods. Both unbleached and bleached pulps are used, depending on the end use requirements.

3. Aspen chemimechanical pulp is typically produced by means of simple chemical (principally sulphite) pre-treatment of chips prior to defibration by refining. The generic technology is not new; it has been in commercial practice for more than 20 years. Current versions include milder chemical pre-treatment for a shorter period of time,and refining under pressurized conditions. Its use includes the production of wood-containing publication papers.

   Typically,aspen chemimechanical pulp is bleached with hydrogen peroxide up to the 80-pts brightness levels. This type of pulp is finding new usees as a lower-cost partial substitute for bleached hardwood as well as softwood chemical (kraft) pulps,in the production of printing and writing,and sanitary tissue papers. However,higher usage in the substitute scheme will depend on development of economical techniques for achieving and maintaining higher levels of pulp brightness.

4. Explosion pulping of sulphite-treated aspen chips prior to refining appeared to have some potential as an alternative means of producing high-yield chemimechanical pulps. Some savings in refining energy and improved pulp strengths have been reported. Some larger scale testing of this technology is required to verify these technical and economic improvements.

5. Aspen sulphite pulp has been produced commercially in North America for more than 30 years. It is used principally in admixture with bleached softwood kraft for the manufacture of high quality printing and writing papers. Recent technical advances in the anthraquinone-catalyzed sulphite pulping in the alkaline regime have opened new possibilities to produce higher yield full-chemical pulp with very good strength properties.

6. Although the technology of kraft pulping of aspen has been known for many years,large-scale commercial production of aspen kraft pulp has only begun in earnest in the 1980's.

   Canadian aspen market kraft pulp has been readily accepted by papermakers in The United States,Europe and Japan. With the exception of bulk and opacity,bleached aspen kraft pulp has similar papermaking properties as bleached eucalyptus pulp. Continued expansion of the kraft aspen pulp in the market place will depend on the relative availability and pricing of the rival eucalyptus kraft pulp.

7. If the successful development of a simple chemical recovery system could be realized,the soda-anthraquinone pulping approach might be an economical alternative to the standard kraft pulping technique. For the chemical pulping of aspen, the soda-anthraquinone technique offers comparable delignification rate,pulping yield,pulp strength and bleachability as the kraft pulping method. Smaller scale pulp mills might be economically practicable.

8. Available technical information suggests that aspen can be readily pulped by means of organic solvents. Because of the uncertain efficiency of spent solvent recovery and inferior pulp strength (relative to kraft),the ultimate economic viability of solvent pulping technology remains highly questionable.

9. There are many technical solutions,economic or otherwise,to the problems of using stained and decayed wood,reducing bark content,and controlling pitch deposition. The needs for new approaches are obvious,but not critical to the expansion of aspen usage in pulping and papermaking.

RECOMMENDATIONS

There is no one technical problem which hinders the promotion and expansion of aspen usage in pulping and papermaking. However,there are several specific topics of manufacturing operations which could improve the efficiency of resource utilization. These major needs are as follows:

1. Optimization of organized techniques for the processing of stained and decayed aspen in the the manufacture of pulp and paper products would be beneficial. Better methods of monitoring wood quality prior to usage,upgrading sub-standard wood (at the mill site),and pulping and bleaching would be desirable.

2. For further expansion of aspen chemimechanical pulp in the substitution of traditional chemical pulps,major improvements in achieving and maintaining high levels of pulp brightness would be required.

3. For the production of chemical pulp,sulphite-anthraquinone and soda-anthraquinone technologies might be further developed as attractive alternatives to the costly large-scale kraft approach. Their successful development could lead to the establishment of smaller economically-viable chemical pulp mills.

4. Greater usage of aspen pulp in the manufacture of paper and paperboard could be accelerated with improved technical knowledge of aspen pulp fibres. New basic research studies on the fundamental properties such as fibre morphology,and the development of specific fibre properties through physical and/or chemical treatment would be beneficial.

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REVIEW OF PULPING AND PAPERMAKING PROPERTIES OF ASPEN

1. INTRODUCTION

Poplar is the common name applied to trees of the genus POPULUS which includes aspens, black or balsam poplars and cottonwoods. Its domain ranges from Newfoundland to British Columbia. The commercial growing stock of poplars is estimated to be about 2.25 billion m^3 [1]. Alberta accounts for about 27% of the total, equivalent to approximately 600 million m^3 [2]. Aspen (Populus tremuloides Michx.) accounts for about 80% of the commercial poplars in Alberta.

The literature on the properties and use of aspen pulp for papermaking is very extensive. Indeed there has been considerable information developed since the 1900's on aspen pulp and papermaking technology [3-6].

The technical and economical benefits of using aspen/poplar has been promoted many times in Canada [7-11] since the late 1910's. But the time was not right for over 70 years. Because of the abundant availability of softwoods in Canada, the usage of aspen for pulp manufacture has been largely ignored until very recently.

2. OBJECTIVES

The objectives of the present study were as follows:

a) To review critically the available technical literature pertaining to the pulping and papermaking properties of aspen (Populus tremuloides Michx.),

b) To identify any deficiencies in the above technical data base, and

c) To recommend future course of action pertaining to the development of relevant data base for the exploitation of aspen as a raw material for the pulp and paper industry

3. METHODOLOGY

The technical literature dating from about 1900 to present was searched manually as well as through computerized information retrieval system ("Paperchem" file in Dialog Information Services Inc.,Palo Alto,CA). Over 2000 literature entries plus unpublished information from the files of Arbokem Inc. pertaining to aspen/poplar pulping and papermaking were reviewed. When possible,specific poplar species,i.e.,aspen,is identified and examples from Canadian experience are used.

Additionally,direct interviews were made with several key technical and marketing personnel of bleached aspen kraft pulp mills and off-shore paper mills which use aspen kraft pulp. For reasons of market confidentiality,these persons have declined to be identified.

Representative samples of Canadian aspen kraft and Brazilian eucalyptus kraft pulps were tested during the course of this study review.

4. TECHNOLOGY

Aspen/poplar may be used to produce mechanical pulp, chemical pulp and combination thereof. The specific end use requirements,market conditions and resource supply situation dictate the most appropriate type of pulp that could be produced economically.

4.1 Mechanical Pulp

4.1.1 Groundwood and Refiner Mechanical Pulps

Aspen/poplar mechanical pulp is generally characterized to have low physical strength,good opacity,good porosity and high bulk [12-14]. The unbleached pulp is typically very bright. And it is readily bleachable further to acceptable brightness economically. These features make the pulp suitable for the manufacture of printing papers.

Because of the general shortage of pulpwood,the European (particularly Italian) industry has been using poplar groundwood for the manufacture of newsprint and groundwood publication papers for many years [15,16]. Several European mills also use poplar refiner groundwood pulp for the manufacture of paperboard [17].

In North America,aspen/poplar mechanical pulps are being used for the manufacture of coated groundwood paper [18-22]. Both stone groundwood and refiner mechanical pulps are in current use. Typically,the aspen/poplar mechanical pulp is used in the range of 30% of the fibre furnish.

As shown in Table I,the representative properties of aspen stone groundwood (SGW) and refiner mechanical (RMP) pulps are shown to be essentially identical. Both pulps were made commercially at the Nitec Paper mill (Niagara Falls,New York) for the production of groundwood publication papers.

In a study of stone and refiner groundwood of spruce and poplar,Marton et al. [23] observed that the length of fibres in the raw material does not have an appreciable effect on strength and optical properties of the resultant groundwood. The width,cell wall thickness and density were noted to be the dominant factors.

Aspen mechanical pulp can also be produced using the thermomechanical pulping (TMP) process. However,it has now been superseded by the chemimechanical pulping (CMP) and the chemithermomechanical pulping (CTMP) processes. In some instances such as integrated pulp and paper production,aspen TMP might still find certain applications. Table II shows the typical quality of TMP made from North American aspen.

TABLE I - Quality Comparison of Commercial Stone Groundwood and Refiner Mechanical Pulps [18]

Properties	Stone Groundwood Pulp*	Refiner Mechanical Pulp*
Freeness,CSF	82	71
Bauer-McNett Fibre Classification		
+28 mesh	2.2	2.7
+48 mesh	14.9	18.9
+100 mesh	24.2	26.1
+200 mesh	21.4	17.4
-200 mesh	37.3	34.9
Bulk,cm^3/g	2.64	2.85
Burst Index,$kPa.m^2/g$	1.33	1.09
Tear Index,$mN.m^2/g$	2.48	2.49
Breaking Length,km	3.06	3.21
Stretch,%	1.35	1.27
Tensile Energy Absorption,J/m^2	1.66	1.57
Brightness,% GE	65.9	63.9
Power Consumption,MJ/kg	6.83	6.45

* Aspen/poplar from the Niagara region of New York State.

Table II - Quality Characteristics of Unbleached Aspen TMP

Properties	Ref. [24]	Ref. [25]
Aspen Source	Saskatchewan (?)	Wisconsin
Freeness,CSF	115	123
Apparent density,kg/m^3	348	321
Burst Index,kPa.m^2/g	0.71	2.06(?)
Tensile Index,N.m/g	26.0	ND
Breaking Length,km	ND	2.53
Tear Index,mN.m^2/g	2.8	2.6
Brightness,% ISO	59.5	ND
Opacity,%	96.5	ND
Light Scattering Coeff.,m^2/kg	65.8	ND
Bauer-McNett Classification,%		
+20 mesh	ND	1
+35 mesh	ND	18
+65 mesh	ND	31
+150 mesh	ND	18
-150 mesh	ND	32
Energy Consumption,MJ/kg	*	8.7

ND = no data

* From Ref. [26],an energy consumption of 7.56 MJ/kg would be needed to produce a 100-CSF aspen TMP.

It may be noted that TMP version requires higher energy consumption than the RMP version without providing a substantially improved pulp (cf. Tables I and II).

At the Biron,Wisconsin mill of Consolidated Papers Inc.,papermachine trials have been conducted in which the mechanical pulp portion of the (coated) base sheet furnish was varied at up to 5% above normal [26]. No printing or strength deficiencies were reported with a blend of either spruce groundwood + aspen TMP or aspen groundwood + spruce TMP.

At the Ontario Paper Co. (Thorold,Ontario),pilot experiments have been made on the use of both debarked and unbarked aspen chips in blend with jack pine for the production of newsprint-grade thermomechanical pulp. Leask [27] reported that acceptable dry pulp strengths can be achieved with either debarked and unbarked aspen in the 30% blend with jack pine.

However,the use of unbarked aspen was observed to give a brightness loss of 5 points and a marked reduction in wet web strength characteristics (See Table III). In the unbarked aspen/jack pine sample,the bark was not found to be present as specks; the colour of the pulp stock was uniform.

In the early 1980's,a pressurized version of the classical stone groundwood pulping process became available commercially. The improved process,known as PGW,was developed by OY Tampella in Finland. The PGW process provides grinding at elevated temperatures and pressures. Karna et al.[28] have recently reported some pilot scale work on the pressure grinding of aspen from the Wisconsin/Minnesota forest area. The aspen wood used was noted to contain 2-3% (by volume) of heartwood decay.

The preliminary test data showed that at a given freeness,the pulp strength of PGW pit stock were markedly higher than that of the conventional stone groundwood pulp. The specific energy consumption was correspondingly about 20% higher for the PGW process. Table IV shows a comparison of the properties of the two types of aspen groundwood pulp. The bleachability of the two types of groundwood pulp was noted to be similar.

TABLE III - Effect of Using Unbarked Aspen Chips in the Production of Jack Pine/Aspen TMP [27]

Wood furnish,%		
Jack Pine	70	70
Peeled Aspen*	30	--
Unbarked Aspen*	--	30
Freeness,CSF	84	94
Burst Index,kPa.m^2/g	1.86	1.67
Tear Index,mN.m^2/g	7.35	6.37
Breaking Length,km	3.63	3.42
Stretch,%	1.61	1.63
Wet web stretch,%	5.64	4.00
Brightness,pts		
457 nm	57.1	52.2
570 nm	70.8	64.9
Printing opacity,%	96.3	97.7
Somerville Shives,%	0.01	0.02
Bauer-McNett Fiber Classification		
+14 mesh	3.8	4.0
+28 mesh	24.5	25.9
+48 mesh	17.9	21.7
+100 mesh	18.7	20.7
+200 mesh	8.3	9.2
-200 mesh	26.8	18.5

* Ontario source

TABLE IV - Comparative Properties of Unbleached Aspen Groundwood Pulps for the Production of Publication Papers [28]

Properties	Stone Groundwood*	Pressurized Groundwood*
Grinder Pressure,kPa	0	300
Shower water temp.,deg C	75	95
Freeness,CSF	92	106
Brightness,% ISO	62.5	61.7
Apparent density,kg/m^3	343	350
Tear Index,mN.m^2/g	2.7	2.8
Tensile Index,N.m/g	17.9	18.4
Stretch,%	2.3	2.5
Burst Index,kPa.m^2/g	0.83	0.90
Scott Bond,J/m^2	122	120
Scattering Coefficient,m^2/kg	78.8	75.5
Wet Strength (25% solids),N/mm	110	122
Wet Stretch (25% solids),%	5.5	7.2

* North American aspen

Karna et al. [28] also provided an interesting comparison of the different energy consumption to produce a 140 CSF pulp. The figures are as follows:

Conventional stone groundwood	3.60 MJ/kg
Pressurized stone groundwood	4.32 MJ/kg
Thermomechanical	6.84 MJ/kg

As in the case of softwood,it is now recognized that PGW pulp can be produced with TMP-like strength properties,at SGW-like energy consumptions. Of course,this process option can be considered only in instances in which roundwood is readily available. This aspect is believed to be one of the major considerations given to the installation of PGW system at the new Lake Superior Paper Industries mill in Duluth, Minnesota. The mill would be using about 50% PGW aspen pulp for the manufacture of coated publication papers. Certainly, the production of PGW market pulp would also merit some considerations.

Aspen mechanical pulp can be bleached readily in one or two stages to acceptable brightness levels [28-30]. The common bleaching chemicals in practice today are H_2O_2 and/ or $Na_2S_2O_4$. Table V illustrates some example properties of bleached aspen mechanical pulps.

In two-stage bleaching (e.g.,peroxide followed by dithionite),aspen TMP can be bleached to the 75-80 pts brightness levels [30].

Table V - Example Properties of Bleached Aspen Mechanical Pulps

Literature Reference	28	28	24
Type of Mechanical Pulp#	SGW	PGW	TMP
Unbleached Brightness,% ISO	62.5	61.7	59.6
Bleaching Conditions	*	*	**
Freeness,CSF	86	86	115
Brightness,% ISO	73.0	72.5	70.0
Apparent density,kg/m^3	362	359	369
Tear Index,mN.m^2/g	2.8	3.1	2.7
Tensile Index,N.m/g	19.3	21.9	28.0
Stretch,%	2.4	2.7	ND
Burst Index,kPa.m^2/g	0.89	1.04	0.75
Scott Bond,J/m^2	149	152	ND
Scattering Coefficient,m^2/kg	72.6	72.7	65.5
Wet Strength (25% solids),N/m	107	120	ND
Wet Stretch (25% solids),%	7.9	8.6	ND

North American aspen

* 2.0% NaOH + 0.8% H_2O_2 + 0.3% DTPA + 2.5% Na_2SiO_3
12 % Consistency at 55 deg.C for 40 minutes

** 1.0% NaOH + 1.0% H_2O_2 + 0.5% DTPA + 4.0% Na_2SiO_3
10% Consistency at 60 deg.C for 180 minutes

4.1.2 Chemigroundwood Pulp

In comparison to softwood groundwood,hardwood mechanical pulp has generally inferior strengths. During the past 30 years,there have been many attempts made to effect improved pulp properties by mild chemical treatment of the whole log prior to mechanical processing. This approach is generally known as "Chemigroundwood Pulping".

In 1950,Libby and O'Neil [31] reported the development of a "Chemigroundwood Process" which could,among other things,provide the use of aspen mechanical pulp in substitution for spruce mechanical pulp in many grades of paper. The Process consists of a mild chemical (neutral sulphite) pre-treatment of wood in block form followed by mechanical defibration in conventional grinders. Brecht [15] reported that chemigroundwood pulp (European poplar) had higher tensile and tear strengths,and lower specific energy consumption than conventional poplar groundwood pulp.

In the mild treatment with neutral sulphite solution before grinding,the freeness and long-fibre fraction of aspen groundwood pulp are increased [32]. In the most current version,peroxide bleaching chemicals are added to the hot shower water circuit of the pressurized grinders [28]. The result has been reported to include improved brightness and strengths,with a concomitant significant reduction in grinder energy consumption. Table VI shows the effect of this approach on Finnish aspen wood.

Similarly,Meinecke [33] reported the use of 4-5% alkaline peroxide treatment of European poplar and birch to give a refiner pulp with properties which are similar to those of softwood refiner groundwood. The brightness of these hardwood pulps were observed to be in the range 70 pts Elrepho brightness.

4.1.3 Chemimechanical Pulp

The chemimechanical pulping (CMP) process is based on the impregnation of hardwood chips in a neutral sodium sulphite solution,followed by refining under atmospheric pressures.

Table VI - Effect of Peroxide Addition during Pressure Grinding of Finnish Aspen [28]

Properties*	Control	Peroxide Added
Freeness,CSF	105	103
Brightness,% ISO	63.3	74.8
Apparent density,kg/m^3	300	353
Stretch,%	2.0	2.5
Tensile Index N.m/g	20.4	25.9
Tear Index,mN.m^2/g	2.9	3.2
Burst Index,kPa.m^2/g	0.79	1.33
Scott Bond,J/m^2	98	176
Scattering Coeff.,m^2/kg	74.4	73.1
Wet Strength (25% solids),N/m	98	105
Wet Stretch (25% solids),%	6.0	6.2
Specific energy consumption,MJ/kg	7.34	4.90

* PGW operation was at 250 kPa pressure and 105 deg.C

One of the interesting features of CMP technology is that for a given supply of wood,a broad range of pulp grades could be made by only changing the main processing parameters such as chemical treatment time and temperature,chemicals applied,and refining energy input and consistency. Judicious combination of chemical and mechanical treatment of hardwood (as well softwood) chips would provide an economical pulp with satisfactory strength and optical properties.

In the 1950 to 1970 period,considerable technical advances were made in the development of chemical treatment of hardwood (aspen) chips as well as improved mechanical defibration techniques [34-45]. A summary of the properties of aspen chemimechanical pulp produced with "1960 technology" is given in Table VII. It is interesting to note that these "optimum" pulp properties achieved were not substantially different from those reported in the more-recent technical literature.

The use of "semichemical" hardwood for newsprint on a commercial basis at the Richmond Pulp and Paper Co. (now Kruger Inc.) in Bromptonville,Quebec was first reported in 1958. Laviste [46] noted that reduction in tear strength is one of the principal obstacles to greater substitution of softwood pulp by hardwood (chemical and/or semichemical) pulp in newsprint.

In the late 1950's,Chidester et al. [41] studied the use of aspen chemimechanical pulp in the manufacture of newsprint. As shown in Table VIII,the "aspen-based" newsprint made on a pilot paper machine had higher strength and brightness than the commercial standard (groundwood/sulphite) newsprint. However,the opacity of the aspen/kraft newsprint was found to be deficient. It is interesting to note that the basis weight was over 50 g/sq. m.,which was typical of the newsprint made in that era.

Table VII - Comparative Properties of Unbleached Aspen Chemimechanical Pulps [41].

	Neutral Sulphite	Cold Soda	Chemi-Groundwood	Groundwood
Pulp Yield,%	88	88	89	97
Energy Consumption, MJ/kg	4.9	2.3	2.7	2.9
Freeness,CSF	180	250	185	70
Apparent Density, g/cm^3	0.61	0.62	0.75	0.40
Burst Index, $kPa.m^2/g$	2.25	3.5	5.3	1.3
Tear Index, $mN.m^2/g$	5.10	6.17	6.86	4.31
Breaking Length,km	4.25	6.35	8.58	3.05
Opacity,%	88	75	75	94
Brightness,% GE	49	(54)	40	59

Table VIII - Substitution of Aspen Chemimechanical Pulp for Softwood Groundwood in Newsprint [41]

	Standard	"Aspen"
Aspen,%	--	80
Southern Pine Kraft,%	--	20
Canadian Softwood Sulphite,%	ca. 20	--
Canadian Softwood Groundwood,%	ca. 80	--
Basis Weight,g/sq.m.	52.3	55.6
Caliper,mils	2.9	3.9
Density,g/cm^3	0.72	0.56
Burst,kPa	51.3	67.9
Tear,mN	237.2	285.7
Tensile Strength,kN/m	1.26	1.78
Folding Endurance,double fold	2	5
Opacity,%	90.2	87.1
Brightness,% GE	60.5	62.3

* Neutral sulphite pre-treatment; 91% pulp yield

Some of the earlier chemimechanical pulping processes for hardwoods such as Stora-Brite [47-49],Blandin [50,51],Kushiro [52,53],and Cold Soda [54-58] are still being practiced in different parts of the World. The Brite-Chem [49] and the Blandin [50,51] processes have been tested on aspen wood. The common sequential steps features of these CMP processes [59-61] are as follows:

1. Short time of (<15 min.) impregnation of chips with a Na_2SO_3 solution at 80 to 170 deg.C.

2. Short period of cooking (up to 60 min.;usually vapour-phase type) at 150 to 180 deg.C.

3. Disc refining in one or two stages.

In the 1980's,chemimechanical pulping of hardwoods, particularly aspen/poplar,has gained considerable renewed interest. In terms of cost and performance,sulphite solution at various pH is still the most preferred chemical for the treatment of wood chips.

Today,several pulp mills in North America are still using the classical CMP technology for the processing of poplar/aspen. For example,Georgia-Pacific Corp. has been operating a 90 MT/day sulphite-based CMP plant in Bellingham (Washington) since 1965. The aspen/cottonwood CMP is blended with softwood sulphite pulp for the production of sanitary tissue paper.

The Appleton Paper Co.(Combined Locks,Wisconsin) has used a CMP-type process for the pulping of aspen since 1965. The pulp mill capacity is about 300 MT/day [59]. Typically, aspen chips are soaked in a sodium sulphite solution for 30 minutes at 90 deg.C under atmospheric condition (e.g.,in a Bauer M&D digester),prior to pressing and refining in two stages at high consistencies. After cleaning,this pulp may be used directly or bleached in a single H_2O_2 stage to improve pulp brightness. For the production of telephone directory and receipt papers,about 50% of this aspen CMP is used in the furnish. The pulp yield is reported to be 90 to 92% and the total energy consumption is of the order of 4 GJ/odt. It was observed that the wood should be fresh (i.e., not more than 4 to 6 weeks after felling),in order to achieve maximum pulp brightness and chemical impregnation

Leask [62] reported that a trial production of newsprint was made in 1968 with 85% poplar CMP and 15% reclaimed sulphite pulp from tab cards. The quality of the experimental newsprint was considered to be comparable to that of the conventional newsprint produced then in the north-eastern region of North America.

More recently,the Appleton mill has replaced the $NaOH/Na_2SO_3$ solution with an alkali peroxide solution. This change permits the elimination of a separate bleaching step. Table IX illustrates the comparative qualities of the two types of aspen CMP at 150 CSF.

The CMP technology is also practiced in Italy for the pulping of poplar,in the production of coated and uncoated printing and writing papers [60,61]. Table X shows the improved qualities of aspen/poplar CMP. It may be noted as in all chemical pre-treatment processes,the resulting pulp yield is always lowered and the refining energy required is also reduced,in comparison to standard mechanical pulping.

Aspen CMP is proposed again today as a partial substitute for conventional hardwood and softwood kraft pulp [65-67] for a wide range of paper grades. Figure 1 shows two process configuration which are commercially available.

Recently,Franzen and Li [67] has completed an extensive study on the effect of various process conditions (e.g.,cooking temperature,cooking liquor pH,cooking time, refining consistency,etc.) on the properties of aspen CMP. These workers concluded that for most grades of pulp with the optimum combination of optical and strength properties,the ideal cooking liquor pH is the range of 7 to 9. For high strength aspen CMP,an alkaline (pH > 9) liquor would be required. Selected data of unbleached aspen CMP from current versions are presented in Table XI. In general,shorter cooking time will result in higher specific energy consumption to achieve a given pulp freeness level.

Table IX - Comparison of Aspen CMP Made with NaOH/Na_2SO_3 and with NaOH/H_2O_2 [62]

Wisconsin Aspen	"Sulphite"	"Peroxide"
Soaking Time,minutes	(30)	90
Soaking Temp.,deg.C	(82-92)	40-60
NaOH,% absorbed	4.8	4.7
Na_2SO_3,% absorbed	6.9	--
H_2O_2,% absorbed	--	1.7
Pulping Yield,%	85	85
Refining Power,MJ/kg	2.44	2.38
Pulp Freeness,CSF	150	150
Bulk,cm^3/g	2.15	1.85
Burst Index,kPa.m^2/g	2.2	3.0
Tear Index,mN.m^2/g	6.9	7.2
Brightness,pts	46	69

Table X - Comparison of Italian Poplar CMP Made with NaOH/H_2O_2 Pre-Treatment [63,64]

Italian Poplar*	RMP	CMP
Impregnation Liquor		
NaOH,%	--	4.0
H_2O_2,%	--	1.7
Na_2SiO_3,%	--	3.0
Pulping Yield,%	92	83
Refining Power,MJ/kg	4.50	3.92
Pulp Freeness,deg.SR	58	53
Bulk,cm^3/g	2.67	2.60
Burst Index,kPa.m^2/g	0.41	0.51
Tear Index,mN.m^2/g	1.37	1.69
Breaking Length,km	1.40	1.74
Brightness,pts	58.8	71.2

* Fresh "end-of-grain" poplar chips

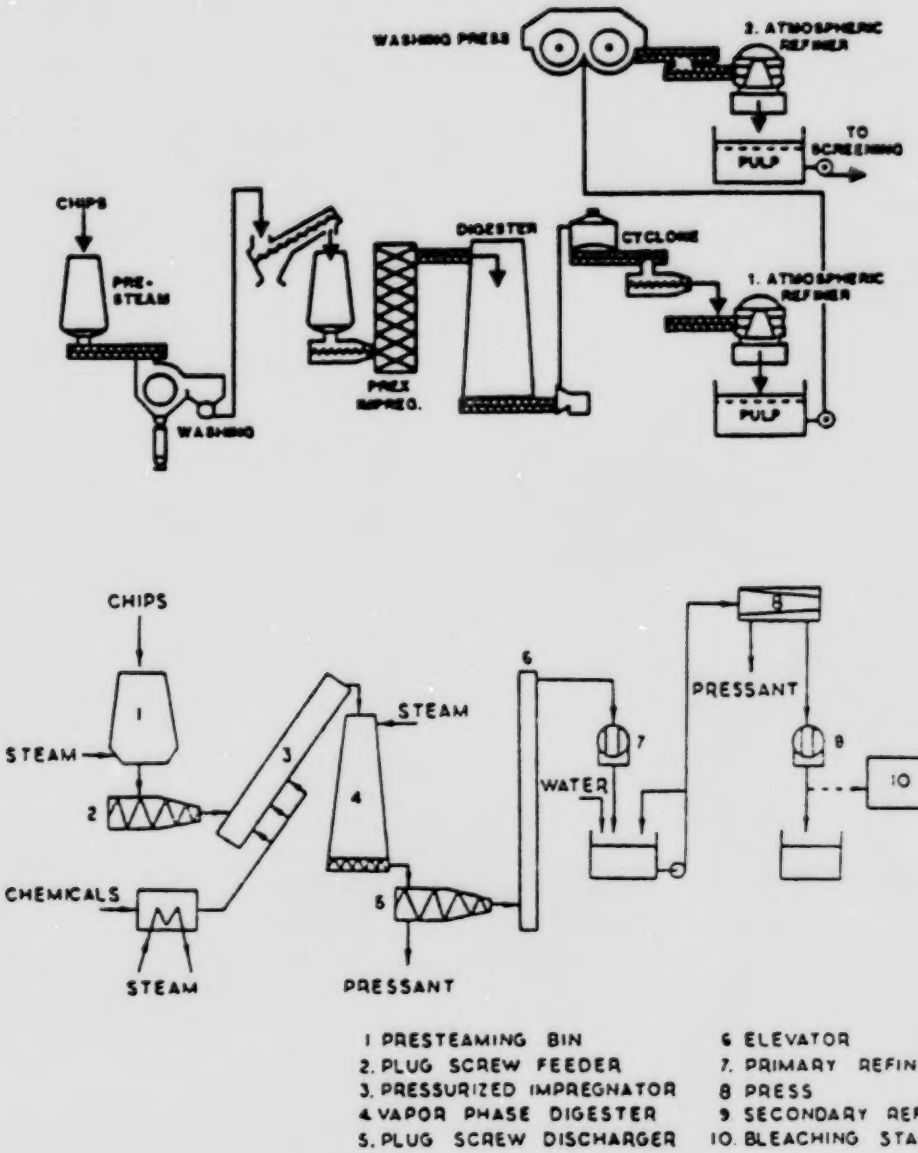


Figure 1 - Typical Aspen CMP Process Configurations [66,67]

Table XI - Selected Properties of Unbleached Aspen CMP

Literature Reference	65	65	67
Aspen wood source	-- North America --		Canada ?
Impregnation/Cooking Liquor			
Na_2SO_3 applied, % on o.d. wood	3.0	20.0	--
NaOH applied,% on o.d wood	1.5	--	--
SO_2 conc. applied,g/l	--	--	30
Liquor to wood ratio	ND	ND	5:1
Initial Liquor pH	ND	9.5	10.0
Cooking Temperature,deg. C	125	160	143
Cooking Time,minutes	8	30	30
Approximate Yield,%	82-88	82-88	93
Specific Energy Consumption, MJ/kg	8.0	3.2	ND
Freeness,CSF	105	150	100
Apparent Density,g/cm^3	0.470	0.695	0.37
Burst Index,$kPa.m^2/g$	2.5	4.1	1.7
Tear Index,$mN.m^2/g$	5.0	5.0	5.8
Breaking Length,km	4.40	6.75	3.12
Opacity,%	92.5	78.5	ND
Brightness,%	48.6	41.5	32.5

ND = no data

At the CIP Gatineau newsprint mill,poplar pulp made from a version of the CMP process has been used in a 25% blend with softwood CMP and bleached kraft pulp for the production of newsprint for several years [68]. In this case,poplar chips (Ottawa Valley region) are blended with softwood chips prior to pulping. This CMP version,known as the "SCMP Process" [69], involves the treatment of wood chips with a solution of Na_2SO_3 to achieve a high level of sulphonation,at an overall yield of about 90%. Refining of the sulphite-treated wood chips is normally made to a freeness of 300 to 400 CSF. Table XII shows the properties of aspen CMP made with two different versions.

As illustrated in Table XIII,aspen CMP can be bleached effectively with hydrogen peroxide and/or sodium dithionite [50,51,67,70,71].

Table XIV shows that the hydrogen peroxide bleaching would increase the strength properties of the aspen CMP. Note that the bleachability of CMP is affected to a certain extent by the pulping conditions used.

Table XII - Quality Comparison of Two Aspen CMP

Literature Reference	68	65
Process	SCMP	CMP
Aspen source	Ottawa Valley	North America
Na_2SO_3 applied,% on wood	12	16 to 20
Liquor pH	7.5-8.0	10.5
Cooking Time,minutes	30	30
Cooking Temperature,deg.C	140	140
Freeness,CSF	350	350
Pulping Yield,%	90	88
Density,g/cm^3	0.490	0.525
Burst Index,$kPa.m^3/g$	1.5	2.75
Tear Index,$mN.m^3/g$	7.1	6.5
Breaking Length,km	4.8	5.0
Opacity,%	82	87
Brightness,%	66	51

Table XIII - Bleaching of Aspen CMP [71]

	American Poplar		Canadian Poplar
Aspen Pulp			
Cooking pH	5.0	7.0	6.7
Pulp Yield,%	85	92	91
Unbleached Brightness,%	58.6	60.4	54.9
Bleached Brightness,%			
1.25% H_2O_2 applied*	73.3	79.0	72.0
1.0% $Na_2S_2O_4$ applied**	66.3	68.5	62.9
1.25% H_2O_2 applied followed with 1.0% $Na_2S_2O_4$ applied	76.1	80.3	NT

* 12-15% consistency at 55 deg.C for 120 minutes

** 4% consistency at 60 deg.C for 60 minutes

Table XIV - Effect of H_2O_2 on the Properties of Aspen CMP

Literature Reference	---- 50 -----		---- 68 -----	
Aspen Source	Michigan		Wisconsin	
H_2O_2 applied,%	--	0.75*	--	3.0**
NaOH applied,%	--	ND	--	1.2
Consistency,%	--	15	--	ND
Temperature,deg C	--	54	--	ND
Time,minutes	--	ND	--	ND
Apparent density,g/cm^3	0.345	0.380	0.461	0.500
Burst Index,$kPa.m^2/g$	0.68	0.95	2.26	2.33
Tensile Index,N.m/g	ND	ND	42.1	51.4
Tear Index,$mN.m^2/g$	2.70	5.15	8.91	8.16
Brightness,%	47.5	68.4	48.0	77.6
Opacity,%	92.2	86.8	ND	ND

ND = no data

4.1.4 Chemithermomechanical Pulping

Chemithermomechanical pulping (CTMP) is still another variation of the basic pulp manufacturing scheme of chemical treatment followed by mechanical treatment. In this case,the chemical treatment is normally very short in duration and the mechanical refining step is effected under pressurized conditions [24,26,61,66,72-81]. In contrast,CMP operation is normally characterized by longer cooking time and refining under atmospheric discharge conditions.

In the case of aspen,it is not always preferable to produce CTMP instead of CMP. Indeed,the physical strength and bonding properties of CMP are recognized to be generally better than those of CTMP at the higher drainage levels [24]. Table XV compares the qualities of aspen CMP,TMP and CTMP. Heitner et Atack [75] have shown that for a given ion content of pulp,the strengths of CMP and CTMP are effectively identical when they are produced at about the same energy consumption level (See Figure 2). For the production of certain grades of paper and paperboard,CTMP is very adequate as an alternative fibre furnish [76]. Its economic attractiveness derives principally from its inherent high yield from wood. But it does not necessarily make a better "universal" pulp.

Aspen CTMP has been used recently in a newsprint production trial at the SCA Matfors mill in Sweden [26,66]. Saskatchewan aspen wood was used. Table XVI presents the newsprint quality of the aspen CTMP newsprint and standard Swedish newsprint.

These trial newsprint rolls were printed in several offset pressrooms Sweden and North America. No difficulties were observed in these printing runs,in comparison to standard newsprint. It is interesting to note that except for the sheet smoothness,the "aspen newsprint" trial which was reported by Chidester et al. [41] in 1960 gave effectively the same results. Aspen CMP or CTMP in admixture with 15 to 20% bleached kraft pulp can be used,without difficulties,in newsprint production. Because a large amount of expensive softwood kraft pulp was needed as reinforcement fibre,the economics of "aspen" newsprint production would appear to be somewhat questionable. It may be noted that the current trend in Canada has in fact been to reduce the use of chemical (kraft) pulp for reinforcement purposes in newsprint production.

Table XV - Quality Comparison of Aspen CMP, TMP and CTMP

Literature Reference*	65	24	24	24
Type of Pulp	CMP	TMP	CTMP	CTMP
Chemicals applied, % on o.d. wood				
Na_2SO_3	20.0	0	1.0	3.0
NaOH	0	0	2.0	6.0
Freeness, CSF	150	100	100	100
Apparent Density, g/cm^3	0.690	0.425	0.481	0.680
Burst Index, $kPa.m^2/g$	4.1	1.00	1.73	2.90
Tensile Index, N.m/g	67.5	24.3	37.7	54.5
Tear Index, $mN.m^2/g$	5.0	2.80	3.6	5.8
Brightness, % ISO	41.5	57.9	57.5	48.2
Specific Energy Consumption, MJ/kg	3.2	7.6	7.5	3.2

* North American aspen used.

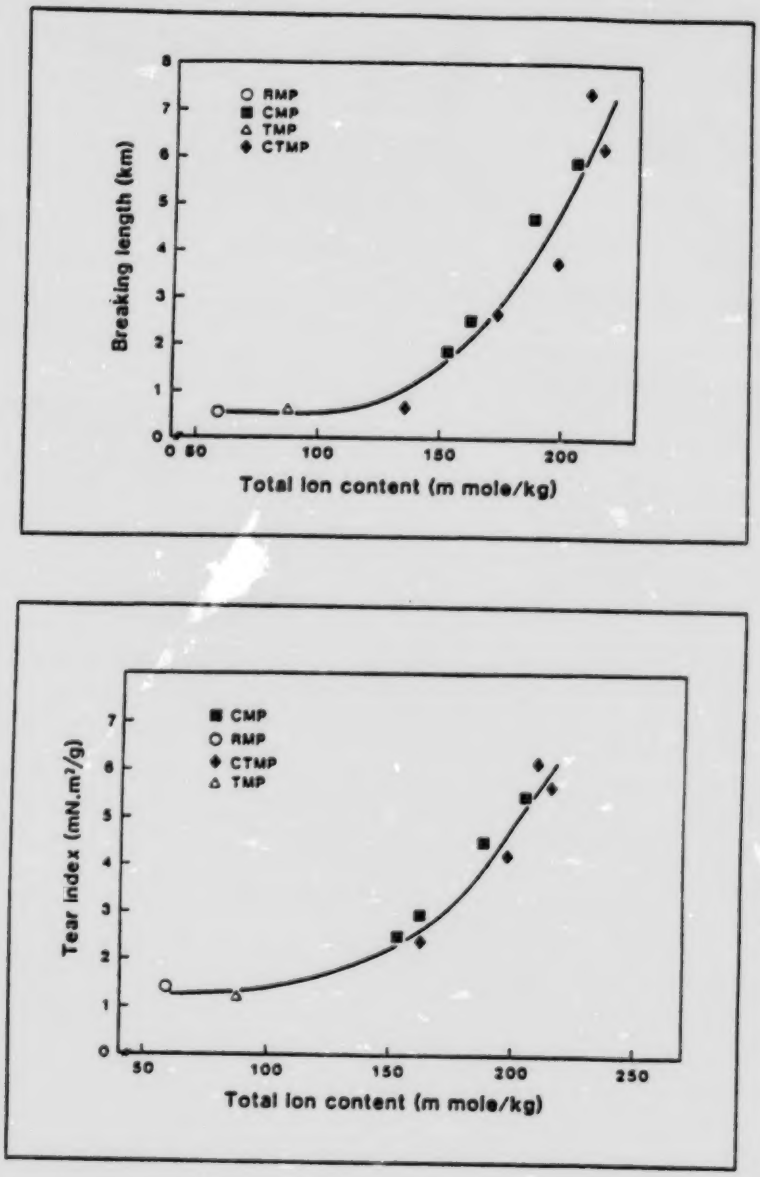


Figure 2 - Relationship between Pulp Ion content and Strength of Aspen CTMP and CMP, produced at an energy input of 3 MJ/kg [75]

Table XVI - Quality Characteristics of Aspen CTMP Newsprint and Standard Swedish Newsprint [66]

	Aspen CTMP Newsprint	Swedish Newsprint
Aspen CTMP,%*	85	--
Softwood SGW,%	--	86
Semi-bleached Kraft,%	15	14
Basis Weight,g/m^2	49.7	50.2
Density,kg/m^3	632	642
Caliper,µm	79	78
Tensile Index,MD,N.m/g	48.6	46.3
Tensile Index,CD,N.m/g	18.4	19.1
Burst Index,$kPa.m^2/g$	1.3	1.6
Tear Index,MD $mN.m^2g$	4.2	4.3
Tear Index,CD $mN.m^2g$	5.5	5.5
Parker Printsurf,10 TS,µm	3.6	3.5
WS,µm	4.4	4.4
Brightness,%	57.5	55.0
Opacity,%	94.4	94.7

* Screened pulp freeness = 89 CSF; aspen pulp was produced at a specific energy consumption of about 6.66 MJ/kg.

Aspen CTMP can be bleached readily to the 75-pts brightness level,using one-stage H_2O_2 bleaching at a peroxide dosage level of about 3% [82]. It has been observed that as the brightness is increased (in peroxide bleaching) the pulp opacity is decreased substantially (See Table XVIII).

Bleached CTMP may be used as a lower-cost substitute for a wide range of paper and paperboard grades [76]. Macmillan Bloedel Research has conducted an evaluation of substitution of hardwood bleached kraft with aspen CTMP in the manufacture of printing and writing paper [76]. As shown In Table XVIII,substitution of 20% aspen CTMP did not cause appreciable reduction in the overall properties of the pulp furnish. The corresponding sheet and printing properties are given in Table XIX. It is evident that the aspen CTMP substitution of the bleached hardwood kraft pulp could be made satisfactorily. The major obstacles to greater usage of aspen CTMP in this grade of paper production are 1) low bleached CTMP brightness,and 2) high brightness reversion.

For the production of sanitary tissue grades,the main parameters are water absorbency,softness,strength and aesthetic appearance. Absorbency is related to bulk. Thus,the higher bulkiness of the aspen CTMP is an advantage. The absorbency rate of aspen CTMP has been tested to compare favourably with that of bleached hardwood kraft pulp [76]. As in the case of printing and writing paper,both low brightness and high brightness reversion are the important obstacles preventing higher greater utilization of aspen CTMP in tissue grades.

In 1985,bleached aspen chemithermomechanical pulp (CTMP) was introduced by Rockhammers AB in Sweden [83]. This pulp has created considerable market demand since its limited introduction. The aspen CTMP grades are mainly used for the production of printing and writing papers. Canadian market entry will be started in mid-1987 when Temcell Inc. (Temiscamingue,Quebec) will begin limited commercial production of bleached aspen CTMP.

Table XVII - Optical Properties of Aspen CTMP Bleached with One-Stage Peroxide and Dithionite [82]

	Unbl.	Single-Stage Peroxide*		Dithionite**	
Chemicals applied#					
NaOH	--	2.0	2.0	--	--
H_2O_2	--	1.0	3.0	--	--
$Na_2S_2O_4$	--	--	--	1.0	3.0
Brightness,% Elrepho	61	71	75	65	66
Opacity,%	91	80	79	89	87

* 12% consistency at 60 deg.C for 120 minutes.
** 4% consistency at 60 deg.C for 60 minutes.
\# % on o.d. pulp

Table XVIII - Selected Properties of Aspen CTMP Furnish for Printing and Writing Paper [76]

Pulp Furnish	Aspen	Test	Control
Aspen CTMP,%	100	20	0
Bleached Hardwood Kraft,%	0	40	60
Bleached Softwood Kraft,%	0	40	40
Freeness,CSF	130	465	560
Drainage Time,sec.	10.3	5.2	4.6
Density,g/cm^3	0.591	0.581	0.582
Tear Index,mN.m^2/g	6.2	10.4	13.0
Burst Index,kPa.m^2/g	3.62	3.40	2.54
Breaking Length,km	7.20	5.84	4.96
Stretch,%	2.3	2.7	2.1
TEA Index,mJ/g	1104	1079	729
Zero Span Tensile Index,N.m/g	157	167	165
Brightness,%	68.8	75.4	81.6
Opacity,%	69.1	69.7	68.4

Table XIX - Selected Sheet and Printing Properties of Aspen CTMP Printing and Writing Paper [76]

	Test	Control
Furnish		
Aspen CTMP,%	20	0
Bleached Hardwood Kraft,%	40	60
Bleached Softwood Kraft,%	40	40
Sheet Properties		
Basis Weight,g/m^2	69.7	68.1
Sheet Density,g/cm^3	0.695	0.698
Sheffield Roughness,ml/min	136	130
Sheffield Porosity,ml/min	196	304
Brightness,%	71	70
Opacity,%	84.5	85.3
Printing Properties*		
Ink Demand,g/m^2 at printing density = 1.0	2.94	2.72
Print through at printing density = 1.0	0.144	0.143

* at 0.65 sheet density

4.1.5 Explosion Pulping

In 1972,O'Connor proposed the "Ammonia Explosion Process" (AEP) for the preparation of aspen pulp [84]. In this process, aspen wood chips are plasticized with ammonia and heat in a system of restricted water content,and fiberized by means of an explosive decompression through a restricted orifice. The AEP aspen pulp was certainly stronger than the conventional mechanical (groundwood or refiner type) pulps. Although no AEP pulp brightness data were reported,it is suspected that the resulting pulp is very dark in colour, perhaps even darker than conventional unbleached kraft pulp.

Recently,Kotka and Vit [85] reported the development of an explosion process for the processing of,among other things,aspen chips. The process,known as the "V-Pulping Process" is based on the impregnation of aspen chips with a Na_2SO_3 solution for a short period time at elevated temperatures (180 to 210 deg.C) and pressures. The steam-cooked chips are then exploded through a discharge device. And the exploded pulp is subsequently refined in conventional equipment. As shown in Table XX,the preliminary V-Pulp test data compare favourably with the CTMP test results.

Although no data have been published on the bleach-ability of this type of aspen pulp,it is expected that the pulp could be bleached in a similar fashion as aspen CMP and CTMP,to the 70-80 pts brightness levels.

Table XX - Quality Comparison of Aspen Exploded and CTMP Pulps [84,85]

	CTMP	V-Pulping	AEP
Literature Reference	85	85	84
Aspen Source	Quebec#	Quebec#	Wisconsin
NH_3 applied, % on o.d. wood	--	--	1.9
Na_2SO_3 applied, % on o.d. wood	10	8	--
Cooking Temperature,deg.C	126	190	113
Cooking Time,minutes	5	4	15
Pulp Yield,%	92	92	90
Pulp Freeness,CSF	119	135	148
Burst Index,kPa.m^2/g	2.6	3.3	2.4
Tear Index,mN.m^2/g	7.2	6.9	5.6
Breaking Length,km	4.5	6.3	4.3
Brightness,%	61	64	ND
Opacity,%	91	89	ND
Refining Energy,MJ/kg	5.2*	2.2**	ND

Aspen used for CTMP and V-Pulping came from different sources.
* Data from pilot plant
** Data from laboratory PFI mill

4.1.6 Corrugating Medium

For the production of corrugating medium, the neutral sulphite semichemical (NSSC) process has been the industry standard for over 40 years [86]. The original process was developed in 1926 at the U.S. Forest Products Laboratory in Madison, WI [13]. The basic process elements are identical to those described for the "new" CMP and CTMP processes. The process involves short-cycle cooking of wood in a Na_2SO_3 solution, followed with mechanical defibration through refiners. In certain cases, ammonium sulphite [87,88] or magnesium bisulphite [89,90] may be used instead of sodium sulphite. The pulp yield range of NSSC pulp for corrugating medium is typically in the range of 75 to 80%. Hardwood is the preferred wood species because of its lower wood cost and its unique stiffness imparted to corrugated boxboard. In Canada, some mills are using 40 to 60% aspen/poplar in the hardwood chip furnish [87].

Unlike pulp for paper manufacture, NSSC pulp for corrugating medium could be manufactured from wood containing certain amount of bark. Table XXI shows the typical properties of NSSC pulp made from rough and peeled aspen [91]. Note that the strength of the "rough" sample was only slightly lower than that of the "peeled" sample.

Table XXI - Comparison of Rough and Peeled Poplar Chips for the Production of Corrugating Medium [91]

Wood Sample (Eastern Ontario)	Peeled	Rough
Chemicals Applied, % on wood*		
Na_2SO_3	4.9	4.9
Na_2CO_3 (free)	4.2	4.2
Spent Liquor pH	9.6	9.3
Pulp Yield, %	78	78
Freeness, CSF	257	292
Bulk, cm^3/g	1.8	1.9
Burst Index, kPa.m^2/g	3.1	2.8
Tear Index, mN.m^2/g	5.7	6.2
Breaking Length, km	6.6	5.6
Concora Crush, N	258	245
Corrugating Stiffness	92	92

* Cooking at 187 deg.C for 15.5 minutes.
Liquor-to-wood ratio (including wood moisture) = 2.5:1

4.2 Chemical Pulping

Chemical pulping is normally characterized by lower yield pulp,particularly pulp in which no mechanical processing is required for defibration. The chemicals used might be identical to those used for the preparation of chemigroundwood and chemimechanical pulps. The demarcation between chemical and chemimechanical pulps might be in the pulp yield range of 60 to 65%.

4.2.1 Kraft Pulping

During the past 30 years,kraft pulping has emerged as the de facto standard process for the production of chemical pulp. It is still the only commercial chemical pulping process which could utilize a very broad range of lignocellulosic materials.

The kraft pulping of Canadian aspen/poplar has been studied in earnest since the early 1940's [4]. In 1959,Legg and Hart [92] completed the first authoritative study of aspen kraft pulps in Canada. But the sulphidity range evaluated by these workers was less than 10%,somewhat low by today's standard kraft pulping practice.

Hatton and Hejjas [93] studied the effects of time, temperature and effective alkali charge on the "standard" kraft pulping of aspen (Populus tremuloides). Alberta aspen wood was used. The pulping yield range of 54 to 64% was investigated. These workers found that pulp yield and $KMnO_4$ number correlated well with effective alkali applied and H Factor,for the range of pulping conditions evaluated.

In a subsequent study,Keays and Hatton [94] investigated the relationship of pulp yield with Kappa number for Alberta aspen. The rate of change of pulp yield with Kappa number was noted to be relatively constant with changes in maximum cooking temperature (168-170 deg.C),time at maximum temperature (10-60 minutes) or liquor-to-wood ratio (4.0-6.5). The following equation was calculated from the experimental for the prediction of total pulp yield:

$$\text{Total Pulp Yield} = 53.70 + 0.198\ \text{Kappa Number(total pulp)}$$

In comparison,the corresponding yield change was found to be greater for changes in effective alkali applied (10-15% on oven-dry wood).

These relationships should be used very cautiously for the estimation of pulping results from other aspen wood sources. Legg and Hart [92] have previously reported the variation in pulp yield and residual lignin content for kraft pulping of aspen/poplar (of different age) sampled from different regions of Canada. Tables XXII and XXIII illustrate these variations.

Table XXII - Kraft Pulping of Aspen (Populus tremuloides) Sampled from Different Regions of Canada [92]

Aspen Source	Wood Density g/cu.cm.	Total Pulp Yield % on wood	Residual Lignin % on pulp	Pulp (CED) Viscosity mPa.s
Ramsay,Ontario (48 years old)	0.356	57.7	2.2	36.9
Wabigoon Lake, Ontario (23 year old)	0.368	56.5	2.3	38.1
Granby,Quebec (37 years old)	0.406	59.4	1.8	35.0
Pine Falls, Manitoba (50 years old)	0.393	57.5	1.9	41.0
Noranda,Quebec (20 years old)	0.390	58.0	1.7	32.3
Harrington, Ontario (30 years old)	0.360	57.3	3.6	42.0

Pulping Conditions:

12% effective alkali charge; 2% sulphide charge; Liquor-to-wood ratio 4:1 (including wood moisture); Maximum temperature 170 deg.C; Time at max. temp. = 90 min.

Table XXIII - Selected Properties of Unbleached Aspen (Populus tremuloides) Kraft Pulps [92]

Aspen Source	Wood Density g/cu.cm.	Total Pulp Yield % on wood	---- 300 CSF ---- Bulk	Burst	BL
Ramsay,Ontario (48 years old)	0.356	57.7	1.18	6.86	12.3
Wabigoon Lake, Ontario (23 year old)	0.368	56.5	1.20	6.76	11.8
Noranda,Quebec (20 years old)	0.390	58.0	1.26	5.78	9.9
Harrington, Ontario (30 years old)	0.360	57.3	1.30	5.88	11.0

Bulk = cm^3/g
Burst = Burst Index,$kPa.m^2/g$
BL = Breaking Length,km

Pulping Conditions:
12% effective alkali charge; 2% sulphide charge; Liquor-to-wood ratio 4:1 (including wood moisture); Maximum temperature 170 deg.C; Time at max. temp. = 90 min.

Hunt and Keays [95] have also studied the kraft pulping of aspen trees of different age group. These workers found that 6-year old aspen could still be used to make an acceptable pulp,albeit at slightly lower yield and higher Kappa number (See Table XXIV).

Table XXIV - Characteristics of Unbleached Kraft Pulp Made from Aspen (Populus tremuloides) of Different Age Class [95]

Ontario Aspen	53-year	16-year	6-year
Total Pulp Yield,%	58.5	59.1	55.4
Screen Rejects,%	1.3	0.3	0.8
Kappa Number	23.0	22.8	25.9
500 CSF			
Bulk,cm^3/g	1.59	1.52	1.54
Burst Index,$kPa.m^2/g$	3.92	2.94	2.45
Tear Index,$mN.m^2/g$	8.53	7.45	6.57
Breaking Length,km	8.3	7.0	7.4
300 CSF			
Bulk,cm^3/g	1.39	1.32	1.30
Burst Index,$kPa.m^2/g$	5.00	5.39	5.59
Tear Index,$mN.m^2/g$	8.53	7.15	6.66
Breaking Length,km	11.0	10.1	11.6

Pulping Conditions:
Max. temp. = 170 deg.C
Sulphidity = 22.7%
Time to max. temp.=130 minutes
Time at max. temp. = 18-32 (varied to achieve Kappa no.=25)
Liquor to wood ratio = 4.4:1
Effective alkali = 14%

Hatton [96,97] has also investigated the effect of chip dimensions on the kraft pulping of aspen (from central B.C. interior). As shown Figure 3,at a given chip length for pulping to a target residual lignin content,high chip thickness will provide lower screened pulp yield,with accompanying lower consumption of effective alkali in cooking.

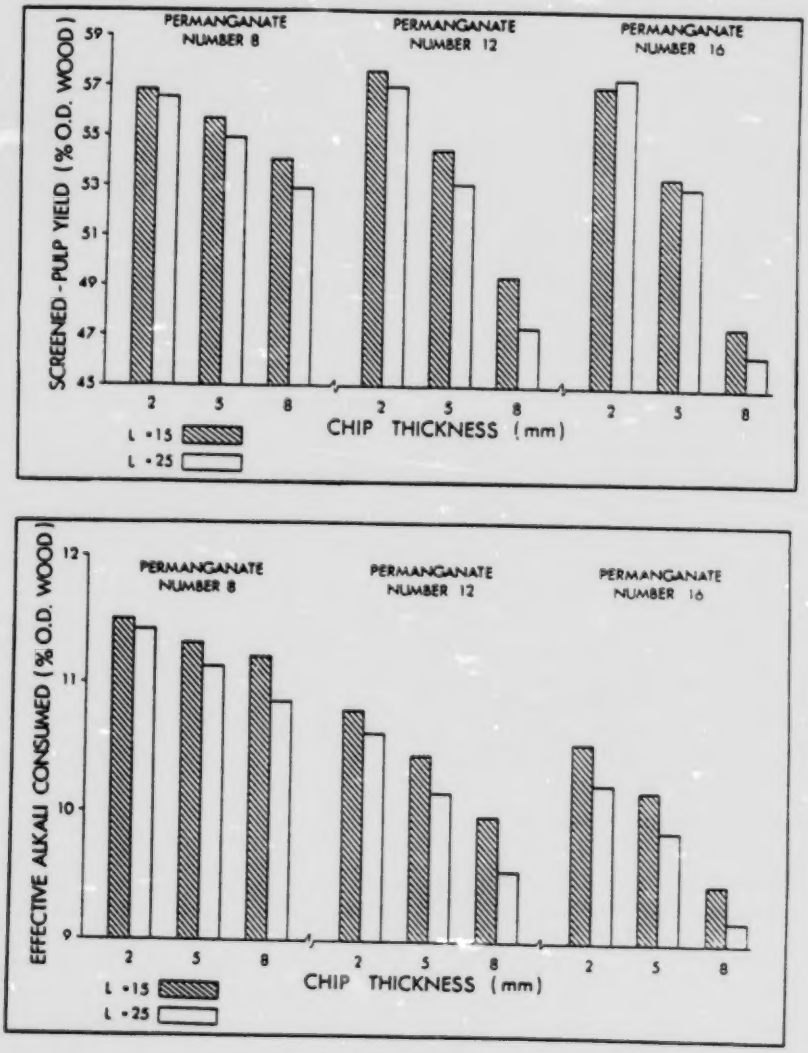


Figure 3 - Effect of Chip Size on the Kraft Pulping of Trembling Aspen [96]

Keays and Hatton [94] suggested that an aspen kraft pulp made at a total yield of 57% (at Kappa number about 17) would have comparable quality to commercial bleached hardwood kraft pulp which is already in the market. Table XXV provides a comparison of the strength properties of several lab-prepared unbleached hardwood pulps. Note that aspen pulp has similar characteristics as white birch and mixed hardwoods. Based on PFI test data,aspen pulp appeared to be easier to refine than the other hardwood pulps.

During the course of this project,several samples of commercial Canadian aspen and Brazilian eucalyptus pulps were tested for their strength and optical properties. Eucalyptus kraft pulp is now generally recognized today to be the premier hardwood market pulp in the World; it has an excellent combination of papermaking characteristics [99-103]. For example,the versatility of the eucalyptus kraft pulp is attested by the production of over 30 different types of paper and paperboard,in which eucalyptus is the primary fibre [102].

Figure 4 shows that the tear-tensile strength characteristics of aspen kraft pulp compare very favourably with those of Brazilian eucalyptus pulps. However,the opacity of the aspen kraft is markedly lower than that of eucalyptus pulp (See Figure 5).

Table XXVI illustrates the comparison of other properties of commercial aspen and eucalyptus kraft pulps. Although there are markedly different physical and optical characteristics,aspen kraft pulp could be expected to be very competitive with eucalyptus kraft pulp,in the production of many grades of paper and paperboard.

Table XXV - Quality Comparison of Several Lab-Prepared Unbleached Hardwood Kraft Pulps

	Aspen*	Aspen*	Mixed Hardwood**	White Birch#
Literature Reference	94	98	98	98
Scr. Pulp Yield,%	57.1	55.7	48.5	53.4
Kappa no.	18	18	15	16
500 CSF				
PFI,rev.	600	22	1000	4440
Bulk,cm^3/g	1.46	1.45	1.55	1.41
Tear Index,$mN.m^2/g$	7.6	7.0	7.2	11.0
Burst Index,$kPa.m^2/g$	4.2	3.4	4.21	6.6
Breaking Length,km	8.7	7.4	7.64	11.1
Stretch,%	ND	1.75	2.42	3.08
300 CSF				
PFI,Rev.	6300	6690	9080	10000##
Bulk,cm^3/g	1.28	1.29	1.40	1.35##
Tear Index,$mN.m^2/g$	8.0	6.9	7.9	10.8##
Burst Index,$kPa.m^2/g$	5.8	5.7	5.8	7.6##
Breaking Length,km	10.2	10.1	9.1	12.0##
Stretch,%	ND	3.2	3.3	3.7##

ND = no data
* Populus tremuloides from Alberta
** Mixed hardwood (mostly maple + poplar) from Eastern Canada
\# Betula papyrifera from Quebec
345 CSF data only

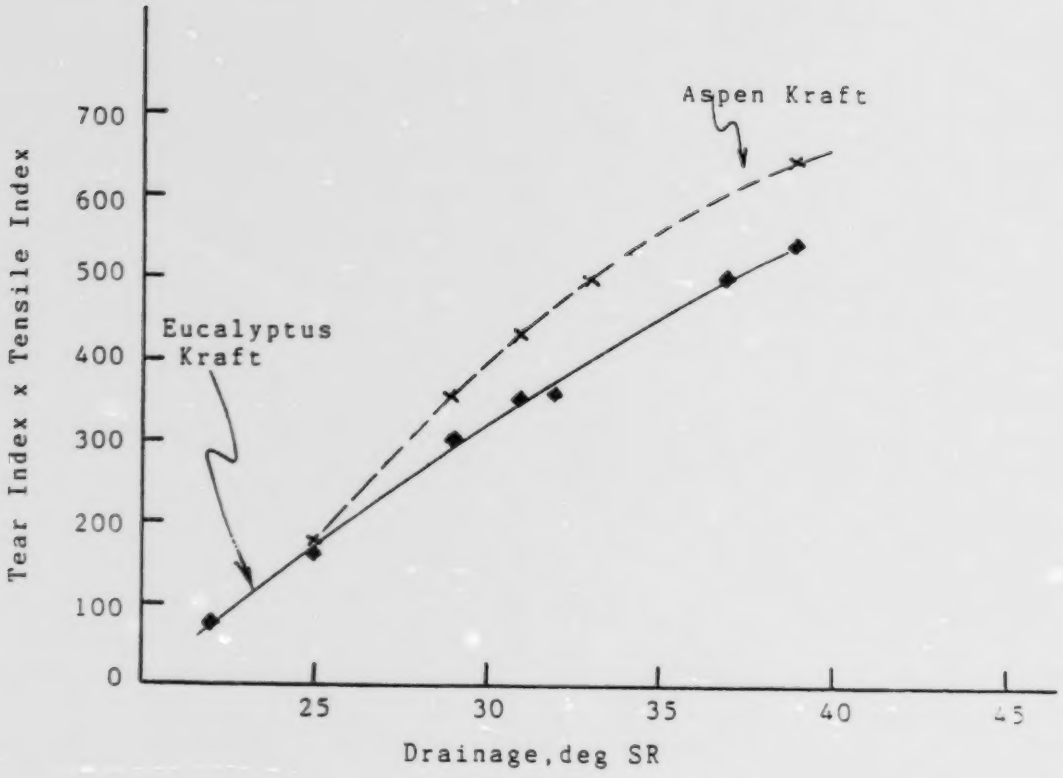


Figure 4 - Comparison of Strength Properties of Bleached Aspen and Eucalyptus Kraft Pulps

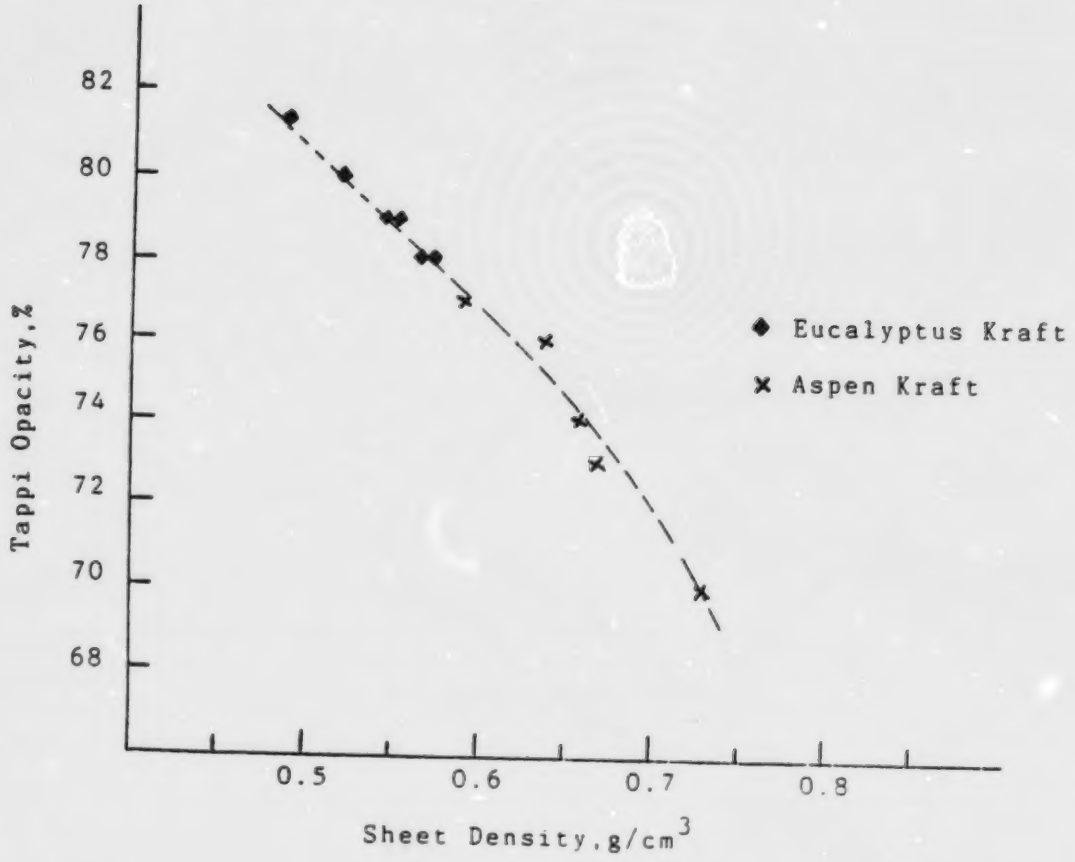


Figure 5 - Comparison of Opacity of Bleached Aspen and Eucalyptus Kraft Pulps

Table XXVI - Quality Comparison of Commercial Bleached Aspen and Eucalyptus Kraft Pulps

	Aspen		Eucalyptus	
	1*	2**	1*	2**
Brightness,% Elrepho	89.2	93.3	90.2	>88
DCM Extractibles,%	0.427	ND	0.144	0.23
Viscosity (0.5% CED), mPa.s	27.5	25.8	18.4	>12
Tappi Dirt Count,ppm	1	ND	< 1	ND
Bauer-McNett Classification,%				
+ 14 mesh	0.4	ND	<0.1	ND
+ 28 mesh	6.4	ND	0.7	ND
+ 48 mesh	37.6	ND	47.1	ND
+ 100 mesh	40.5	ND	38.2	ND
- 100 mesh	15.1	ND	14.0	ND
500 CSF				
Bulk,cm^3/g	1.69	1.66	1.92	1.85
Tear Index,$mN.m^2/g$	6.47	6.9	4.91	7.9
Burst Index,$kPa.m^2/g$	0.88	ND	1.18	3.4
Breaking Length,km	2.80	3.8	3.30	6.45
Opacity,%	77	75	80	79
300 CSF				
Bulk,cm^3/g	1.37	1.45	1.76	1.55
Tear Index,$mN.m^2/g$	8.34	7.9	9.81	10.7
Burst Index,$kPa.m^2/g$	4.51	ND	2.75	7.0
Breaking Length,km	7.70	7.8	5.50	10.7
Opacity,%	70	68	78	76

* Labortory test data from the present study
** Pulp manufacturers' technical literature

Since the early 1980's,several large kraft pulp mills in Canada have begun,in rapid succession,the commercial production of bleached aspen kraft pulp. Current production is estimated to be in the range of 600,000 admt annually. The major market aspen kraft pulp producers in Canada today include:

Great Lakes Forest Products (Thunder Bay,Ontario)
Weyerhaeuser Canada (Prince Albert,Saskatchewan)
Procter and Gamble Cellulose (Grande Prairie,Alberta)
James River-Marathon (Marathon,Ontario)
Eddy Forest Products (Espanola,Ontario)
Kimberly-Clark Canada (Terrace Bay,Ontario)

Eddy Forest Products is probably earliest producer of aspen kraft pulp in Canada [10]. In just a few short years,Canadian aspen kraft pulp has established a permanent place in the export markets. The pulp is well accepted by papermakers in the United States,Europe and Japan.

Several other Canadian pulp mills are also producing hardwood kraft pulp which contain certain amount of poplar/ aspen fibres. These pulps are generally classified as "Mixed Northern Hardwoods".

Various attempts have been made over the years to improve the kraft pulping of aspen. In a laboratory study, Kleinert and Marraccini [104] reported that vapour-phase kraft cooking of poplar would result in pulps of low lignin content and good strength properties. The basic procedure involves the impregnation of chips at 130 deg.C for 15 minutes,followed by removal of the impregnation liquor and cooking at 185 deg. C for 10 min. This research work contributed to the subsequent commercial development of the "two-vessel" continuous cooking technique. Table XXVII shows the strength properties of "vapour-phase" and conventional aspen kraft pulps.

The use of AQ in the kraft pulping of aspen has been investigated by Blain [105]. Over the sulphidity range of 0 to 25% studied,Blain found that the addition of AQ would provide significant benefits,in terms of faster pulping rate, lower alkali requirements,improved yields and higher pulp viscosities. Moreover,it was observed that AQ and sulphidity may be considered as interchangable process variables. Figure 6 illustrates the relationships between pulp yield and Kappa number,at different levels of AQ dosage.

Table XXVII- Comparison of "Vapour-Phase" and Conventional Kraft Aspen Pulps

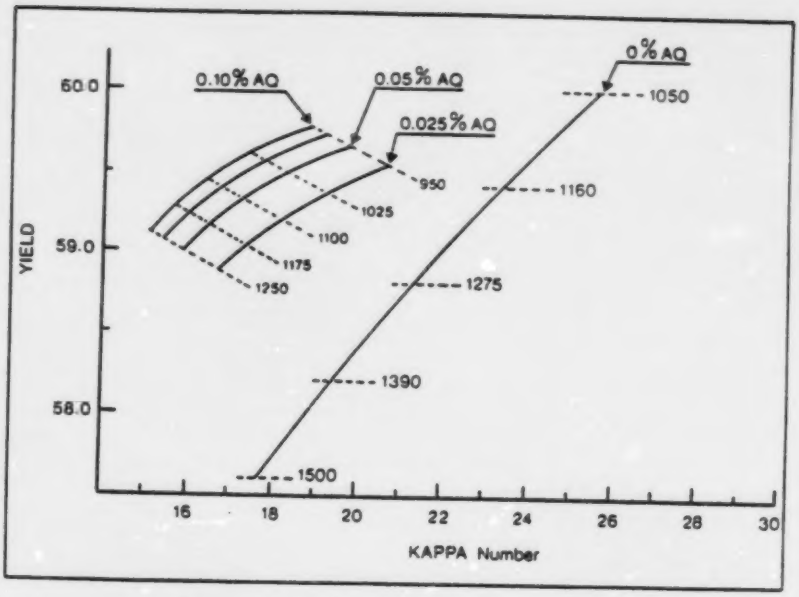
	Conventional*	Vapour-Phase**
Literature Reference	94	104
Total Yield,%	57.1	54.1
Screened Rejects,%	< 0.1	0.03
Screened Pulp Lignin,%	ND	2.0
Kappa number	18	ND
0.5% CED Viscosity,mPa.s	ND	31.5
500 CSF		
Tear Strength,mN.m^2/g	7.9	7.1
Breaking Length,km	7.6	7.3
300 CSF		
Tear Strength,mN.m^2/g	7.8	7.4
Breaking Length,km	11.3	12.1

ND = no data

* Standard Cooking Conditions:
Time-to-max.temp. = 135 minutes
Time-at-max. temp. = 60 minutes
Max. temp. = 170 deg.C
Effective alkali,% on wood = 12
Sulphidity,% = 25 %
L:W ratio = 4.5:1

** Vapour-Phase Impregnation
Liquor:Wood = 10 to 20:1
Sulphidity = 25%
Time = 15 minutes
Temperature = 130 deg.C

Cooking
Time-at-max. temp. = 10 minutes
Max. temp. = 185 deg.C



Basis: Maximum temperature = 170 deg.C
Effective alkali charge = 12.0%
Liquor to wood ratio = 4:1

Figure 6 - Effect of Anthraquinone Addition on the Kraft Pulping of Aspen [105]

Oxygen delignification has been considered by many workers to be an effective means to effect higher overall bleached yield and higher strengths of aspen kraft pulp. The study of Hunt and Hatton [106] on white birch suggested that higher strength,but not higher yield,is achievable with such a pulping/bleaching procedure. Other benefits included lower screen rejects and faster beating of the pulp. Unfortunately,no detailed work has been reported for aspen.

The combined kraft pulping of aspen/softwood is proposed as a means to extend the limited wood resource. Hunt and Hatton [107] and Kent and Hatton [108] have found that a mixture of 90% softwood and 10% aspen would have virtually identical strength characteristics as the 100% softwood pulp (See Table XXVIII).

Table XXVIII - Relative Pulp Yield and Strength Quality of Kraft Pulp made from Mixtures of Trembling Aspen/White Spruce [107]

Aspen,% in softwood	Pulp Yield	Burst Strength	Tear Strength	Tensile Strength
0*	100	100	100	100
10	101	104	97	104
20	102	95	93	97

* Relative to white spruce which was designated 100

Hunt has also studied the pulping of trembling aspen in admixture with other hardwoods [109]. The study objective was to determine the best possible combination of Canadian hardwood species,in terms of desired pulp yield and pulp quality. Chip thickness was chosen as a major study parameter. Hunt found that 6-8 mm thick aspen (a faster cooking species) chips may be used in admixture with thinner (2-6 mm) chips of the slower cooking species (e.g.,beech,birch and maple) without any adverse effects on overall pulp yield and pulp lignin content.

Hatton and Gee [110] have also evaluated the kraft pulping of aspen chips with softwood (mainly black spruce and jack pine) fines. The aim was to extend the overall wood resource for pulp production. These workers found that up to 20% softwood fines may be used with aspen chips to produce bleached "hardwood" pulps with beating and mechanical properties similar to those from the cooking of 100% aspen chips (See Figure 7). However,the aspen chips/softwood fines mixture took longer cooking time and lower yield,when cooked to a given Kappa number (See Figure 8).

Another means to extend hardwood supply for the pulp mill is to use non-merchantable part of the tree and/or short-rotation whole-tree chips [111-115]. In a study of European aspen (Populus tremula),Lonneberg [113] reported that whole-tree (aspen) chips may be used up to 25% with regular hardwood chips to produce bleached pulp of acceptable quality.

Whole tree aspen/poplar is presently used at the Domtar fine paper mill in Cornwall,Ontario [114,115]. Poplar is grown on a 15-year rotation cycle in nearby "plantations". The chips made from unbarked poplar (containing about 7% bark and 2.5% twigs) are routinely blended with regular hardwood,in the amount of about 15% of the the total wood furnish. At the Cornwall kraft pulp mill,the use of whole-tree poplar chips has been noted to increase alkali consumption and to demand higher degree of efficiency from the mill's pulp cleaning system.

Table XXIX shows example quality of kraft pulp made from whole-tree aspen/poplar chips.

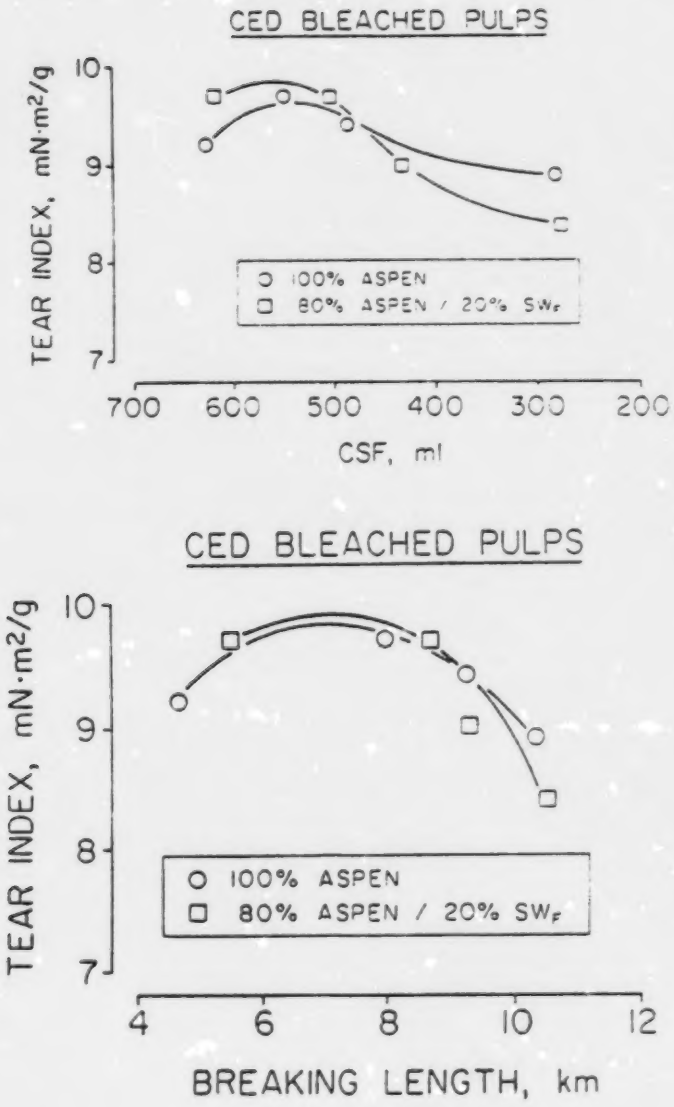
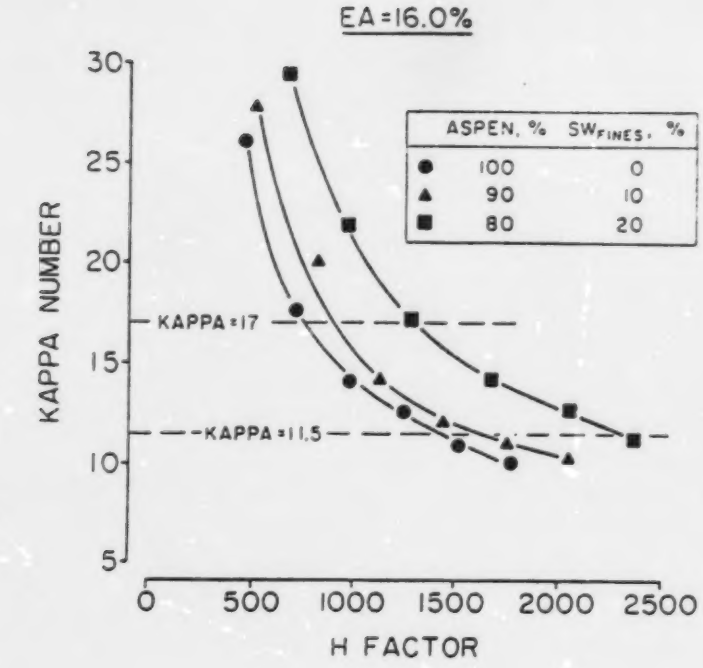


Figure 7 Selected Properties of Aspen Pulp Containing Softwood Fines [110]



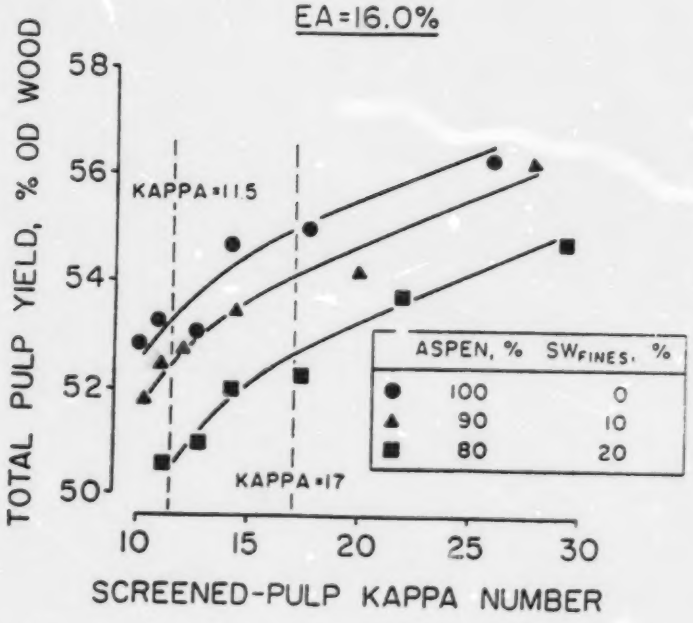


Figure 8 - Kraft Pulping of Aspen Chips with Softwood Fines [110]

Table XXIX - Example Quality of Whole-Tree Short-Rotation Hybrid Aspen/Poplar Kraft Pulp

Literature Reference	114	113
Poplar/Aspen Source	Ontario	Finland
Age Group	10-15	20-25
Bark Content,%	9	ND
Total Pulp Yield,%	56.1	51.5
Screen Rejects,%	ND	3.1
Kappa number	10.6(?)	16.1
Freeness,CSF	450	400
Bulk,cm^3/g	1.70	1.29
Breaking Length,km	11.8	6.97
Tear Index,$mN.m^2/g$	10.5	6.5
Burst Index,$kPa.m^2/g$	10.6	4.6

ND = no data

4.2.2 Soda Pulping

Cold soda pulping of softwoods and hardwoods is a well-known technique. Because of its inability to process softwood efficiently,this chemical pulping has been in decline for the past 50 years in North America. Today,there are only two chemical pulp mills (Hammermill Paper Co. in Erie,PA and Mead Corp. in Kingsport,TN) using the cold soda process for the pulping of mixed hardwoods [86]. The soda hardwood pulp is bleached to high brightness for use in the production of printing and writing paper.

Technical interest in the soda pulping process was renewed almost 10 years ago with the discovery of the catalytic effect of anthraquinone and related chemicals in alkaline pulping [12]. Softwoods as well as hardwoods could be pulped rapidly to acceptable yields and physical strengths. In the absence of sulphur in the chemical liquor system,the soda-AQ process also offers the advantages of a simplified alkali recovery/regeneration system [116],and elimination of odoriferous gas emissions.

Gadda and Brunn [117] has studied the soda-AQ pulping of European aspen (Populus tremula L.). The benefits of AQ addition at the 0.1% (based on o.d. wood) level were very apparent. When pulping was made to a pulp Kappa number of about 30,the yield was noted to increase by 5% with a concurrent 30% decrease in cooking time. Table XXX further illustrates the effectiveness of soda-AQ pulping technique. The Kappa number of 16 is the range that is normally considered to be acceptable for the production of bleachable grades.

Macleod and Cyr [118] have investigated the soda-AQ pulping of Alberta aspen. The study showed that soda-AQ aspen has effectively the same yield,physical properties and bleachability as kraft aspen. The pulping rate was found to be comparable to the "standard" kraft approach. For example,with the use of 0.05% AQ,the soda process could provide a Kappa 18 pulp with a cooking degree (H-Factor) of 1500. Standard kraft process would require the same cooking degree to achieve the same Kappa no. pulp. Table XXXI shows that at the same bleaching conditions,soda-AQ and kraft pulps have comparable brightness. The slightly higher bleached yield for the soda-AQ pulp might compensate for the added cost of AQ usage. Figure 9 illustrates the tear-tensile strength relationship for the CEDED-bleached* pulps.

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* CEDED = chlorine/ caustic extraction/chlorine dioxide/ caustic extraction/ chlorine dioxide

Table XXX - Soda-AQ Pulping of European Aspen [117]

	Control	Test
NaOH,% on o.d. wood	20	20
AQ added,% on o.d.wood	0	0.1
Liquor:wood	4:1	4:1
Time to Max. Temp.,min.	90	90
Time at max. Temp.,minutes	90	90
Max. Temperature,deg.C	170	170
Total Yield,%	55.9	55.2
Kappa number	29.4	16.0

Table XXXI - Comparison of Soda-AQ and Kraft Aspen Pulps [118]

	Soda-AQ	Kraft
Unbleached		
Kappa No.	17.2	17.7
Pulp Yield,%	58.2	54.8
Bleached*		
CE Kappa No.	2.6	2.6
Brightness,% ISO	88.8	89.8
Pulp Yield,%**	56.1	54.8

* Identical CEDED bleaching conditions for the two types of pulp.
** Based on o.d. wood

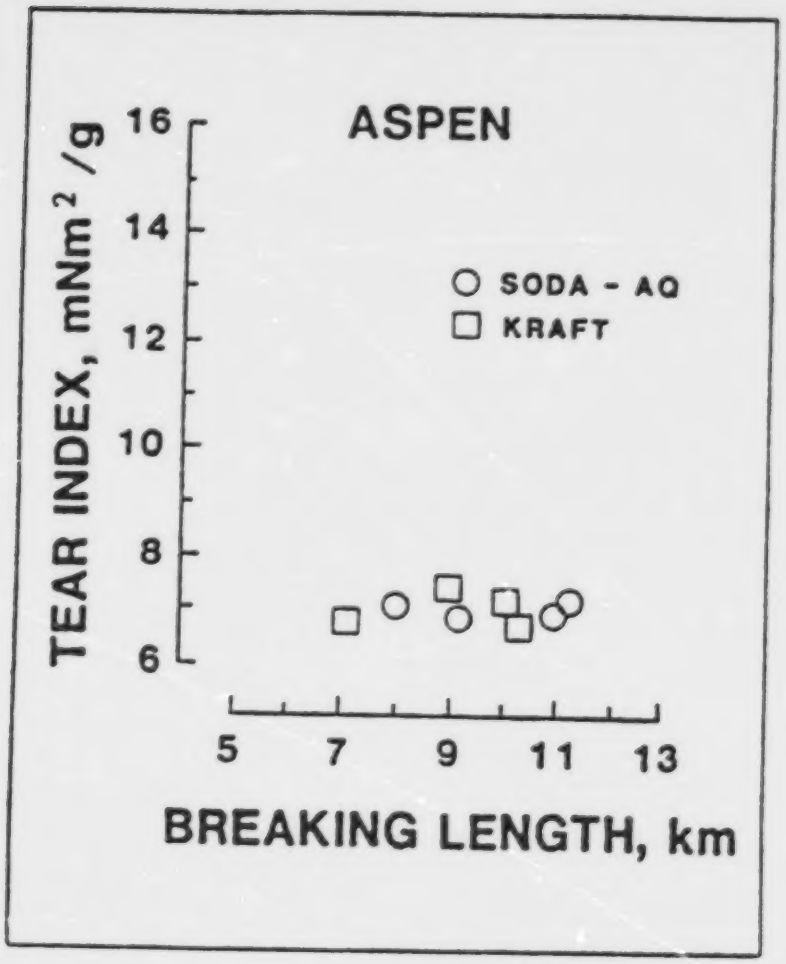

Figure 9 - Tear-Tensile Strength Relationship of Bleached Soda-AQ and Kraft Aspen Pulps [118]

4.2.3 Sulphite Pulping

In 1882,the first sulphite mill in North America began operation in East Providence,Rhode Island [119]. Poplar made up about one-third of the wood furnish at this sulphite pulp mill.

During the past 60 years,there have been many studies conducted on the sulphite pulping of aspen/poplar [120-123]. Many of them are frequently made in pulping regimes which are considered high-yield chemimechanical in nature [123-125]. Aspen/poplar were noted to be easily delignified under acidic sulphite conditions [120-123] to give very bright pulp. Aspen/poplar may be pulped using any of the four commercial bases: sodium,calcium,magnesium and ammonium.

In a study of sodium bisulphite cooking of hardwoods, Dorland et al. [123] have observed that aspen/poplar may be cooked together with softwoods with full development of individual strengths. In other words,the strength of the pulp mixture reflects essentially the proportion of each type of wood used. Aspen/poplar was also noted to give higher pulp yield than maple,when cooked to a given Kappa number.The strength of aspen/poplar bisulphite pulp has been reported to be the highest at the pulp yield range of 62% [123].

The use of poplar/aspen in sulphite mills are still prevalent today. In North America,the aspen/poplar sulphite pulp mills are all located in Wisconsin [86,126]. These pulp mills are all integrated with papermill operations. Typically, bleached aspen sulphite is mixed with bleached softwood kraft pulp for the production of printing and writing papers. The aspen/poplar sulphite pulp mills are as follows:

Mill	Pulping Base	Nominal Capacity
Nekoosa Papers Inc. Port Edwards,WI	Magnesium	200 MT/day
Wausau Paper Mills Co. Brokaw,WI	Magnesium	390 MT/day
James River Corp. Green Bay,WI	Calcium	150 MT/day
Weyerhaeuser Co. Rothschild,WI	Calcium	190 MT/day
Badger Paper Mills Inc. Peshtigo,WI	Ammonium	135 MT/day (50% poplar/aspen)

As discussed in previous Sections,the current trend in paper-grade sulphite production is towards higher yield neutral sulphite techniques. Recently,sulphite pulping of hardwoods for the production of a full-chemical pulp has also been actively investigated in the alkaline regime. Because of its lower wood density,aspen might be uniquely suitable for the production of high-yield chemical pulp using a sulphite-anthraquinone process.

Wong [127] has reported the neutral sulphite-anthraquinone (NSAQ) pulping of aspen. The total pulp yield was reported to be 58-62%. This range is 3 to 8% higher than that could be achieved by the kraft pulping process. As shown in Figure 10,the strength of this new NSAQ aspen pulp would likely to be as strong as other hardwood kraft pulps. Preliminary test results suggested that the pulp could be readily bleached in two stages to high brightness levels. The unbleached pulp brightness is typically in the range of 58% brightness.

Macleod [128] has recently investigated the alkaline sulphite-anthraquinone (ASAQ) pulping of aspen for the production of full-chemical pulp. The ASAQ pulping liquor used was more alkaline than the NSAQ pulping approach. The high yield (60%+) and high unbleached brightness level (65%+) of alkaline sulphite-AQ pulping of aspen were confirmed.

Figure 11 shows that the CEDED-bleached ASAQ and kraft pulps have similar strength characteristics. Macleod has also reported that a 3-stage (CED,for example) could be used to produce a 91+ pts brightness pulp. In comparison,aspen kraft pulp bleached in 5 stages would only attain a brightness level of only 90 pts.

Sulphite-AQ pulping (of hardwoods and softwoods) is generally recognized to be twice as slow as kraft pulping,to reach a given Kappa number level [86,127,128]. However,this aspect may or may not be serious. It has already been established for sulphite-AQ pulping of softwoods that oxygen delignification is the ideal supplementary means to treat sulphite-AQ pulp prior to bleaching. There is considerable evidence to suggest that an oxygen delignification might be the solution to overcome this process disadvantage. In one version,NSAQ or ASAQ pulping might be terminated at a high Kappa number (i.e.,shorter cooking time) level. And the pulp would then be oxygen-delignified to the bleachable Kappa number range.

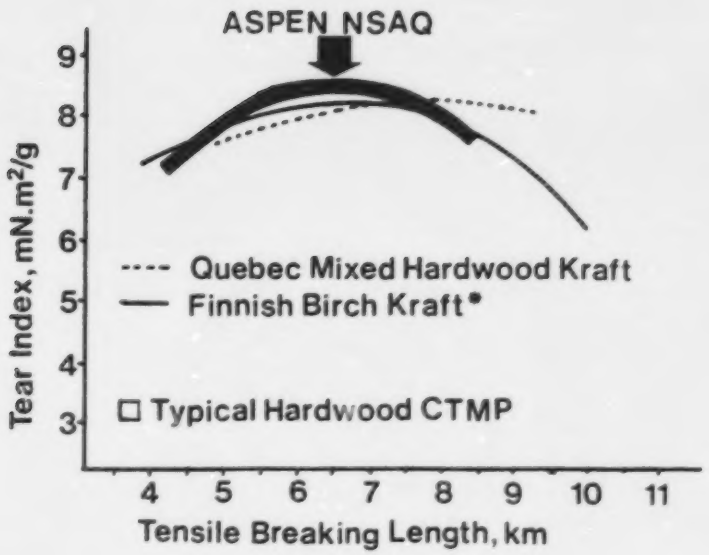

Figure 10 - Strength Comparison of Unbleached NSAQ Aspen and Other Kraft Hardwood Pulps [127]

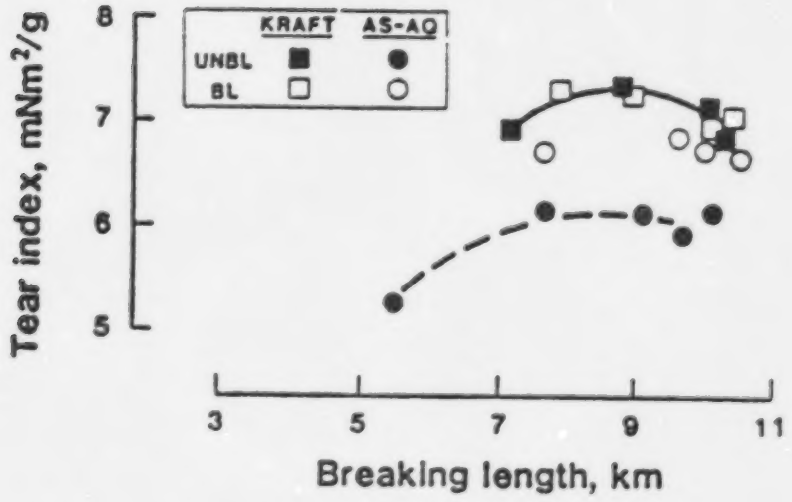

Figure 11 - Strength Comparison of Bleached ASAQ and Kraft Aspen Pulps [128]

4.2.4 Solvent Pulping

Solvent pulping (or commonly known as organosolv pulping) has been studied for more than 50 years [129,130]. Even at elevated temperatures,delignification can proceed effectively only in the presence of a catalyst. Some of the solvent systems which had been investigated include ethanol, methanol,phenol [129],dimethyl sulphoxide [131],hexamethylene diamine [132],and acetic acid/ethyl acetate [133,134,136].

In comparison to the conventional kraft pulping process,organosolv pulping encounters problems in efficient solvent recovery,and acceptable pulp strengths. However,in the case of dissolving pulp production,a solvent pulping approach might have a potential application [135].

Aziz and McDonough [136] have recently reported that ester (acetic acid/ethyl acetate) pulping technique may be used to prepare aspen pulp of lignin content. As shown in Table XXXII,the physical properties of the ester pulp were intermediate between conventional kraft and sulphite pulps. These workers found that other hardwoods (and softwoods) are less readily pulped with the ester solvent system.

Table XXXII - Comparison of Unbleached Ester Aspen Pulp Strengths [136]

	Conventional		Ester Pulping	
	Sulphite	Kraft		
Pulp Yield,%	44	54	53	64
Kappa number	20	12	10	23
Freeness,CSF	450	465	420	397
Bulk,cm^3/g	1.36	ND	ND	1.34
Burst Index,kPa.m^2/g	3.0	5.0	3.4	3.2
Tear Index,mN.m^2/g	4.6	10.5	5.2	4.6
Breaking Length,km	5.9	8.7	7.1	7.1

ND = no data

5. SPECIAL PROBLEMS

5.1 Decayed Wood

It has been estimated that substantial decays are present in mature aspen stands in Alberta [137]. The presence of discoloured and decayed is a major problem in pulp production. The problem is particularly acute when high brightness of unbleached mechanical pulp is desired [138].

5.1.1 Mechanical/Chemimechanical Pulping

Becker and Briggs [139] have studied the effects of stained and decayed aspen on bleached CTMP production. As shown in Table XXXIII,good-strength unbleached and bleached pulp could be produced from decayed aspen. However,pulp brightness is a serious problem. The "decayed" pulp brightness could be 5 to 10 points less than the "sound" pulp. These workers also found that CTMP made under less-severe "sulphite treatment" conditions would result in greater loss of pulp brightness and strength. Stained wood also can affect CTMP quality. Table XXXIV illustrates the combined effect of decayed and stained wood for the production of bleached CTMP. Unfortunately,no assessment of unbleached and bleached pulp yield was made in this study.

Separately,Jackson et al. [24] have also reported similar findings. Decay was observed to have the most deleterious effect on pulp brightness and pulp bleachability. For example,unbleached "sound" aspen gave a 57% brightness whereas "decayed" aspen provided a brightness as low as 40%. At any given peroxide charge level,"decayed" aspen pulp is always more difficult to bleach than "sound" aspen pulp. The unbleached pulp yield was reported to be related to the degree of decay. The yield difference could be as high as 3%,if the fines loss on chip screening was included. These workers suggested that high-grading of chips might be required to produce high quality CTMP.

Table XXXIII - Comparison of CTMP Made from Decayed Aspen Wood [139]

Decay,%	0	1	7	31
Unbleached				
Freeness,CSF	213	203	204	197
Brightness,%	60.7	53.2	51.6	49.8
Bulk,cm^3/g	2.40	2.35	2.35	2.42
Burst Index,kPa.m^2/g	1.5	1.3	1.2	1.5
Tear Index,mN.m^2/g	5.0	4.1	4.0	4.8
Breaking Length,km	3.8	3.2	3.1	3.9
Bleached				
Freeness,CSF	151	154	155	184
Brightness,%	79.9	77.3	74.2	74.6
Bulk,cm^3/g	1.70	1.63	1.65	1.74
Burst Index,kPa.m^2/g	2.8	2.7	2.6	2.7
Tear Index,mN.m^2/g	6.5	6.6	6.1	5.9
Breaking Length,km	5.7	5.5	5.5	5.2

CTMP Test Conditions:
15% Na_2SO_3 applied (pH =8); Cooking for 15 minutes at 125 deg.C; Refining in the laboratory refiner to 200 CSF.

CTMP Bleaching Conditions:
Pre-treatment with 0.5% DTPA; Bleaching with 3-4% H_2O_2 at 60 deg.C for 180 minutes at 10% consistency.

Table XXXIV - Comparison of Bleached Aspen Pulp made from Decayed and Stained Wood [139]

Stain,%	0	55	53	31	54
Decay,%	0	11	35	61	5
Freeness,CSF	139	102	148	71	120
Brightness,%	77.4	67.7	68.2	61.3	70.6
Bulk,cm^3/g	1.49	1.52	1.50	1.53	1.65
Burst Index,kPa,m^2/g	3.4	2.9	3.3	2.8	2.3
Tear Index,mN.m^2/g	5.4	5.1	3.9	3.7	4.2
Breaking Length,km	6.0	5.3	5.9	5.8	5.2

CTMP Test Conditions:
15% Na_2SO_3 applied (pH =8); Cooking for 15 minutes at 125 deg.C; Refining in the laboratory refiner to 200 CSF.

CTMP Bleaching Conditions:
Pre-treatment with 0.5% DTPA; Bleaching with 3-4% H_2O_2 at 60 deg.C for 180 minutes at 10% consistency.

5.1.2 Chemical Pulping

Sheridan [140] has studied the effect of decayed aspen on the chemical pulp yield and quality. Sulphite,soda and kraft pulping processes were evaluated under mill and laboratory trial conditions. Table XXXV illustrates the severe loss of pulp yield from the use of decayed aspen/poplar. The general observation was that despite lower yield,there was no appreciable loss of pulp strength.

Becker and Briggs [139] have recently investigated the kraft pulping of decayed aspen from Alberta. These workers found that at the same pulping conditions,the total pulp yield was lower and the residual lignin (Kappa number) was higher for pulp made from decayed wood (See Table XXXVI). Furthermore,bleached pulp made from wood with advanced decay gave markedly lower strength.

Macleod et al. [141] have studied the upgrading of decayed aspen chips for kraft pulping. These researchers found that normal chipping and screening would be inadequate to remove sufficient heart rot from the decayed wood to render the screened accept chips suitable for kraft pulping. Since it is not economically practical to harvest only sound aspen,a pulp mill will need to deal with the decayed wood problem, under most circumstances. The PAPRIFER Process has been evaluated as a means to upgrade such decayed aspen chips effectively. This Process is based on the segregation of decayed wood from sound wood by differences in density and mechanical strength,in a water medium. The recovered "decayed wood" fraction could be used as a fuel or a substrate in enzymatic processess [141,142]. As shown in Figure 12, PAPRIFER-upgraded chips have similar pulping characteristics as sound aspen chips.

Several methods have been proposed to quantify the degree of decay and to predict pulping response. Hunt and Hatton [143] have reported that the 1%-caustic solubility test correlates well with pulping yield for a wide range of wood species,including aspen (See Figure 13). A ball-milling technique may also have potential as a rapid method for the monitoring of decayed wood [144].

Table XXXV - Loss of Pulp Yield with the Use of Decayed Aspen/Poplar [140]

Pulping Process	Total Pulp Yield,%	
	Sound Wood	Decayed Wood
Sulphite (Mill basket cooks)	50.8	40.0
Soda (Mill basket cooks)	51.9	38.9
Kraft (Laboratory cooks)	51.6	49.8

Table XXXVI - Kraft Pulping of Decayed Aspen [139]

	Active Alkali,%	Kappa number	Total Yield %	Rejects %
Sound Roundwood	15	16.0	56.7	0.5
Sound Slabwood	15	15.5	56.3	0.9
Stained Wood	16	21.5	54.7	5.8
Incipient Decay Wood	17	22.5	52.9	9.8
Advanced Decay Wood	17	19.5	49.0	4.2

Pulping Conditions:

Sulphidity = 27%; Liquor to wood ratio = 4.0:1
Time to max. temp. = 60 minutes
Time at max. temp. = 60 minutes
Maximum temperature = 170 deg.C

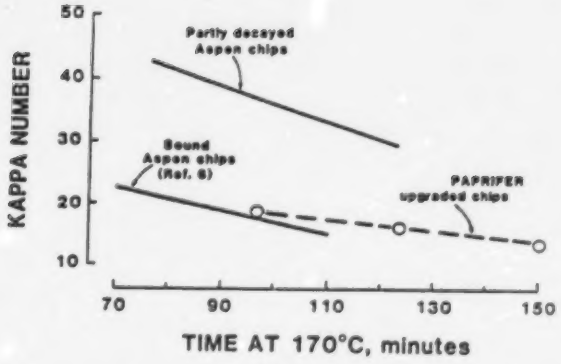

Figure 12 - Kraft Pulping Characteristics of Upgraded Aspen Chips [141]

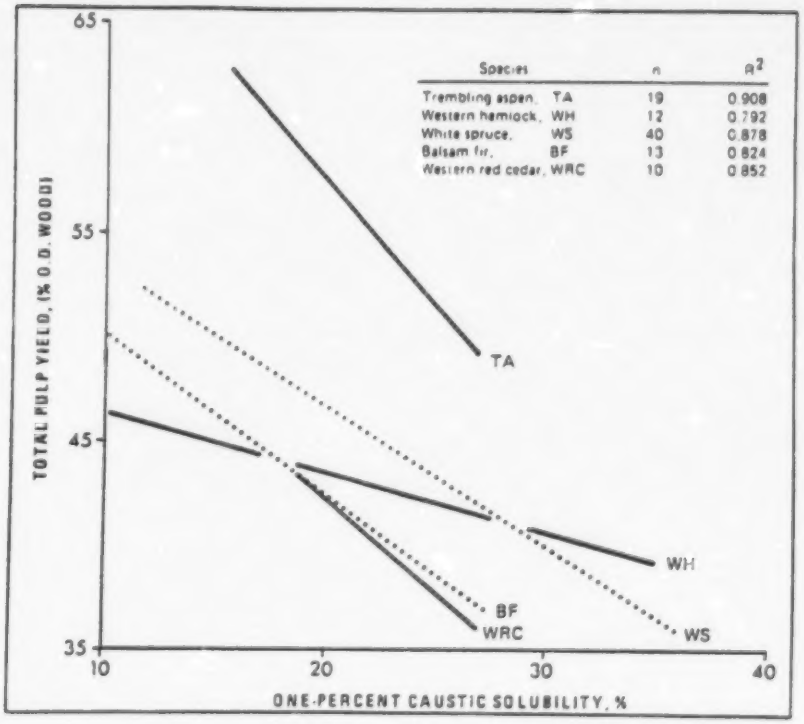

Figure 13 - Relationship between One-Percent Caustic Solubility and Kraft Pulp Yield [143]

5.2 Bark Content

For the production of high-grade pulp and paper products,it is essential to have wood with low bark content. Both mechanical and sulphite pulping processess have low tolerance for bark (content < 0.5% typically) in the wood furnish. In contrast,kraft pulping process could accept chips with as much as 4% bark content [145].

There are several factors affecting the efficacy of debarking aspen wood. Aspen wood can be debarked (by peeling) without difficulties if the logs were harvested in the spring and stored until the Fall before use [145]. Figure 14 shows the strong seasonal effect on bark adhesion.

The temperature effect on debarking efficiency has been studied [146]. The adhesion of bark to wood might be 2 to 5 times stronger in frozen logs than in thawed logs [145]. Indeed,many aspen kraft pulp mills in Canda have been reported problems in efficient debarking of aspen logs dring the winter months. This problem is accentuated with the prevalence of dry debarking technique. It is less efficient than wet debarking of frozen logs. Pre-steaming of the frozen logs are being practiced with varying degree of success. The high bark content in wood chips typically manifests as a cleanliness problem in finished pulp product.

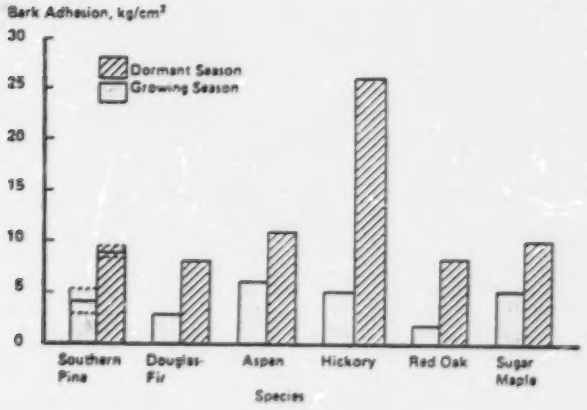

Figure 14 - Bark Adhesion of Several Wood Species [146]

5.3 Pitch

Aspen is known to contain high quanity of ether-soluble substances [147-149]. This material often contributes to the pitch problem in pulping and papermaking operations [147]. It has been known for many years,that seasoning of wood in log or chip form,would decrease the ether-soluble extractives in both wood and bark. Table XXXVII shows the decrease in ether-extractibles in aspen wood and bark which have been stored for 7 months.

Table XXXVII - Extractives in Aspen Wood and Bark [147]

Extractibles*	Freshly-Cut Wood	Freshly-Cut Bark	Seasoned Wood	Seasoned Bark
Ether	2.7	9.6	1.5	3.4
Alcohol-Benzene	1.1	10.8	2.1	7.3
Hot Water	1.1	4.1	1.8	4.9

* % on oven-dry,unextracted wood basis

Outdoor storage of aspen chips were confirmed to be effective in the reduction of ether-extractibles and depositable pitch in sulphite pulp [150]. The optimum chip storage time for "pitch control" was found to be 2 to 3 months. However,for chip pile formed during the coldest month, a chip storage of up to 6 months would be needed to achieve the same "pitch reduction" effect. For storage in log form,a period of about 12 months would be required. These workers have found that in sulphite pulping,over-ageing of chips resulted in significant loss of unbleached pulp brightness and bleachability.

Although aspen is known to be more readily biodegradable,extended storage of aspen under anaerobic conditions had little or no appreciable effects on the wood density or kraft pulp yield [151]. As shown in Table XXXVIII,the pulp strength properties were not affected substantially.

In addition to wood storage,there are also various other means of controlling pitch deposit problems in pulp mills [152]. The techniques in use today include the use of surfactants,dispersants (e.g.,talc) and tall oil addition.

Table XXXVIII - Effect of Anaerobic Storage of Aspen Chips on Unbleached Kraft Pulp Properties [151]

	Control	Chips Stored Under N_2 and CO_2	
Storage Months	0	6	26
Total Pulp Yield,%	55.4	53.8	55.4
Kappa number	11.2	11.4	13.8
500 CSF			
Burst Index,kPa.m^2/g	5.78	5.98	5.78
Tear Index,mN.m^2/g	6.96	6.27	6.27
Breaking Length,km	10. 4	10.9	10.6
Density,g/cm^3	0.75	0.77	0.76
300 CSF			
Burst Index,kPa.m^2/g	7.15	7.15	6.86
Tear Index,mN.m^2/g	6.47	5.68	5.49
Breaking Length,km	12.0	11.8	12.1
Density,g/cm^3	0.81	0.82	0.82

6. CONCLUSIONS

A detailed review of available technical information on aspen pulping and pulp properties has been completed. The papermaking aspects of aspen pulp were reviewed in the context of the specific pulping process. The major findings are as follows:

1. Aspen can be and has been used for the production of good quality mechanical,chemimechanical and chemical pulps.

   The use of market aspen pulp,chemimechanical (e.g.,CMP and CTMP) and chemical (e.g.,kraft),is still relatively new in the manufacture of paper and paperboard.

2. Aspen mechanical pulp has been used as a major furnish (up to 30%) component for the manufacture of coated and uncoated groundwood publication papers.

   It may be produced by the classical stone groundwood, pressurized groundwood,refiner and thermomechanical pulping methods. Both unbleached and bleached pulps are used, depending on the end use requirements.

3. Aspen chemimechanical pulp is typically produced by means of simple chemical (principally sulphite) pre-treatment of chips prior to defibration by refining. The generic technology is not new; it has been in commercial practice for more than 20 years. Current versions include milder chemical pre-treatment for a shorter period of time,and refining under pressurized conditions. Its use includes the production of wood-containing publication papers.

   Typically,aspen chemimechanical pulp is bleached with hydrogen peroxide up to the 80-pts brightness levels. This type of pulp is finding new usees as a lower-cost partial substitute for bleached hardwood as well as softwood chemical (kraft) pulps,in the production of printing and writing,and sanitary tissue papers. However,higher usage in the substitute scheme will depend on development of economical techniques for achieving and maintaining higher levels of pulp brightness.

4. Explosion pulping of sulphite-treated aspen chips prior to refining appeared to have some potential as an alternative means of producing high-yield chemimechanical pulps. Some savings in refining energy and improved pulp strengths have been reported. Some larger scale testing of this technology is required to verify these technical economic improvements.

5. Aspen sulphite pulp has been produced commercially in North America for more than 30 years. It is used principally in admixture with bleached softwood kraft for the manufacture of high quality printing and writing papers. Recent technical advances in the anthraquinone-catalyzed sulphite pulping in the alkaline regime have opened new possibilities to produce higher yield full-chemical pulp with very good strength properties.

6. Although the technology of kraft pulping of aspen has been known for many years,large-scale commercial production of aspen kraft pulp has only begun in earnest in the 1980's.

   Canadian aspen market kraft pulp has been readily accepted by papermakers in The United States,Europe and Japan. With the exception of bulk and opacity,bleached aspen kraft pulp has similar papermaking properties as bleached eucalyptus pulp.

7. If the successful development of a simple chemical recovery system could be realized,the soda-anthraquinone pulping approach might be an economical alternative to the standard kraft pulping technique. For the chemical pulping of aspen, the soda-anthraquinone technique offers comparable delignification rate,pulping yield,pulp strength and bleachability as the kraft pulping method. Smaller scale pulp mills might be economically practicable.

8. Available technical information suggests that aspen can be readily pulped by means of organic solvents. Because of the uncertain efficiency of spent solvent recovery and inferior pulp strength (relative to kraft),the ultimate economic viability of solvent pulping technology remains highly questionable.

9. There are many technical solutions,economic or otherwise,to the problems of using stained and decayed wood,reducing bark content,and controlling pitch deposition. The needs for new approaches are obvious,but not critical to the expansion of aspen usage in pulping and papermaking.

7. RECOMMENDATIONS

There is no one technical problem which hinders the promotion and expansion of aspen usage in pulping and papermaking. However,there are several specific topics of manufacturing operations which could improve the efficiency of resource utilization. These major needs are as follows:

1. Optimization of organized techniques for the processing of stained and decayed aspen in the the manufacture of pulp and paper products would be beneficial. Better methods of monitoring wood quality prior to usage,upgrading sub-standard wood (at the mill site),and pulping and bleaching would be desirable.

2. For further expansion of aspen chemimechanical pulp in the substitution of traditional chemical pulps,major improvements in achieving and maintaining high levels of pulp brightness would be required.

3. For the production of chemical pulp,sulphite-anthraquinone and soda-anthraquinone technologies might be further developed as an attractive alternative to the costly large-scale kraft approach. Their successful development could lead to the establishment of smaller economically-viable chemical pulp mills.

4. Greater usage of aspen pulp in the manufacture of paper and paperboard could be accelerated with improved technical knowledge of aspen pulp fibres. New basic research studies on the fundamental properties such as fibre morphology,and the development of specific fibre properties through physical and/or chemical treatment would be beneficial.

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